UNCTAD/ITD/TEC/10

UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

FROM TECHNOLOGICAL COMPETENCE BUILDING TO COMPETITIVENESS:

CHALLENGES FOR PUBLICLY FUNDED R & D IN INDIA A CASE STUDY OF THE NATIONAL CHEMICAL LABORATORY, PUNE

UNITED NATIONS

Distr.
GENERAL

UNCTAD/ITD/TEC/10
30 September 1993

Original: ENGLISH
ENGLISH, FRENCH AND
SPANISH ONLY

FROM TECHNOLOGICAL COMPETENCE BUILDING TO COMPETITIVENESS:

CHALLENGES FOR PUBLICLY FUNDED R & D IN INDIA A CASE STUDY OF THE NATIONAL CHEMICAL LABORATORY, PUNE

A report by
R. A. Mashelkar, Director,
National Chemical Laboratory, Pune, India
and R. R. Hirwani, Head, Project Planning and Development Unit
National Chemical Laboratory, Pune, India
in cooperation with the UNCTAD secretariat

The designations employed and the presentation of the material in this publication do not imply the expression of any opinion whatsoever on the part of the Secretariat of the United Nations concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delimitation of its frontiers or boundaries.

GE.93-53728

Table of contents

	Paragraphs
INTRODUCTION	1-6
CHAPTER I. THE NATIONAL CHEMICAL LABORATORY (NCL) IN THE BROADER SETTING	
A. Science and technology-related policies and the R & D scenario in India	8-17
B. The Indian chemical industry and the National Chemical Laboratory	18-26
CHAPTER II. CASE STUDIES OF TECHNOLOGIES AND RELATED SERVICES DEVELOPED BY NCL	
A. Xylofining technology	28-33
B. Albene technology	34-39
C. Encilium technology	40-46
D. Metal replacement by polymeric materials in engineering applications	47-55
E. Pesticide technologies	56-64
F. Chlorosilane technology	65-74
G. Consultancy services	75-79
H. Beyond the cases	80
CHAPTER III. RESEARCH & DEVELOPMENT FOR COMPETITIVENESS	
A. Prospects in a new economic environment	82-84
B. Identification of market opportunities for NCL's activities	85-86
C. Initiatives at the NCL level	87-108
D. Concluding remarks	109-113

INTRODUCTION

1. As reaffirmed at UNCTAD VIII in Cartagena, the revitalization of technology flows and of investment, and their contribution to developing countries' efforts towards development requires, inter alia, an increase in their scientific and technological capacity, in order to modify and adapt technology from abroad, as well as to generate and develop technology domestically. The importance of investment in capacity-building, including research and development (R&D), innovation, adaptation and development of technologies was stressed. In the context of the increasing interdependence of nations, and of the globalization of the world economy, UNCTAD VIII also emphasized the need to take account of the diversity of country situations and experiences, with a view to sharing experiences, concerns and views. Such an approach constitutes an essential element of the work programme of UNCTAD's Ad Hoc Working Group on the Interrelationship between Investment and Technology Transfer, established at Cartagena.

2. The present report centres on the experience of a national public-funded R&D institution in a developing country, the National Chemical Laboratory (NCL), in Pune, India. Against the background of the liberalization of the Indian economy, it retraces NCL's efforts to reinforce its technological competence and strengthen its competitiveness. The experience of NCL has to be examined within the context of the science and technology setting and related policies. By the early 1950s, India had recognized the importance of science and technology (S & T) for development, adopting policies and programmes for promoting pure, applied and industrial research and for establishing the corresponding infrastructure. Its expenditure on S & T during the Seventh Plan worked out to about one per cent of GNP, significant as compared with most developing countries and their average of 0.2 per cent for the equivalent period.

3. The development of S & T capabilities can be observed in the chemical industry, currently constituting approximately half of the gross industrial production, with an annual growth rate of 10 per cent-15 per cent in the 1980s and an increasingly important contribution to exports in segments such as pharmaceuticals, dyes, agrochemicals and inorganics. The NCL, a science and knowledge-based research, development and consulting organization established in the beginning of the 1950s, has played an important role in the sector. The first fifteen years of NCL were devoted to creating a competent scientific research capability in chemistry and chemical engineering. In the late 1960s and early 1970s, NCL conducted a considerable amount of applied research work in the development of processes for industrial chemicals facilitating import substitution. In the late 1980s, NCL aimed at developing its competitiveness, including the promotion of its own emerging technologies.

4. To illustrate this development, the report presents selected cases of technologies and technology-related services developed by the NCL. The case histories cover different aspects, such as reasons for project choice and relevance to trade and development requirements, approaches adopted, factors influencing the commercialization of R & D results, interactions among the groups basically making up the R & D infrastructure - that is, national laboratories and research institutions/associations, universities and enterprise in-house R & D centres - and cooperation agreements reached with the enterprise sector. The cases focus on the evaluation by NCL of the results obtained, which has guided the organization in developing its technological competence and in laying down strategies for increasing a competitive edge.

5. The paper is organized around three chapters. Chapter I situates the NCL within the broader setting of India's S & T-related policies and R & D scenario, and within that of the chemical industry. Chapter II examines a sample of cases of technology and technology-related services developed by NCL, focusing on lessons drawn by the organization. Chapter III analyses NCL's prospects in an increasingly market-oriented economic setting and identifies market opportunities for its activities. It also presents initiatives envisaged at the level of NCL for responding to the new challenges. Finally, the chapter provides some concluding remarks based on the experiences of Dr R. A. Mashelkar and Mr R. R.

Hirwani, authors of the report and Director of NCL and Head of NCL's Project Planning and Development Unit, respectively.

6. The present report has benefited from written comments by Mr M.S. Sahni, Vice President, Research, Hindustan Lever Limited, Bombay; and by Mr K.V. Swaminathan, Director, Asian and Pacific Centre for Transfer of Technology (APCTT), New Dehli. The UNCTAD secretariat expresses its appreciation for their assistance.

Chapter I

THE NATIONAL CHEMICAL LABORATORY (NCL) IN THE BROADER SETTING

7. The experiences of the National Chemical Laboratory have to be examined within the context of the Indian science and technology setting and of the related policies, the overall broader R & D scenario and the chemical industry in India, with which NCL deals extensively. The present chapter briefly introduces these elements.

A. Science and technology-related policies and R & D scenario in India

1. The policy setting

8. The Indian Government has given high priority to the development of science and technology during the last several decades. In 1958 it adopted the Scientific Policy Resolution and as a result various mechanisms were set up, such as the Scientific Advisory Committee to the Cabinet (SACC), the Committee on Science and Technology (COST), the National Committee on Science and Technology (NCST), the Cabinet Committee on Science and Technology under the Prime Minister's Chairmanship, and the Scientific Advisory Committee to the Prime Minister (SAC-PM). The Scientific Policy Resolution was aimed at promoting and sustaining science and scientific research efforts in all its aspects - pure, applied and industrial. A sound institutional base for science and technology and industry was created, with a wide range of S&T institutions, a significant number of people and substantial resources devoted to research and development. During the Seventh Plan (1985-1990) such resources represented about one per cent of the Indian GNP.

9. In 1983 the Government of India announced the Technology Policy Statement (TPS), which has guided S&T planning as well as investments in R&D during the past decade. As its objectives the TPS emphasized support for domestic technology development with technological self-reliance and the reduction of dependence on foreign inputs, particularly in designated critical and vulnerable areas. Incentives were to be provided to users of domestically-developed technology, and for products and processes resulting from such use, with preferential treatment given through fiscal and other measures in favour of products made with domestically-developed technologies. The utilization of Indian consultancy would be promoted; foreign technical collaboration or consultancy would utilize designated Indian consulting engineering organizations whenever possible. In general, the TPS aimed at protecting domestic technology, specifying that import of technology and foreign investment in this regard would be permitted on a selective basis. It further outlined a commitment to promoting the absorption, adaptation and subsequent development of imported know-how through adequate investment in research and development to which importers of technology would be expected to contribute.

10. Several incentive schemes were launched during the 1980s with a view to promoting and supporting industrial research. Recognized R & D units and institutions could import required research-related raw materials, special chemicals, and other components, under the Open General Licence; there was no ceiling on the expenditure on imports for R & D. Incentives were created for the utilization of technologies based on domestic R & D efforts, including weighted tax deductions, accelerated depreciation allowance, enhanced investment allowance, and custom duty exemption on scientific equipment imported by non-commercial institutions. In the case of indigenously developed technology, preferential treatment in licensing was accorded to industry. In November 1988, the Government of India, recognizing the need for investing capital in commercializing new, untried technologies and in promoting potential entrepreneurs, issued the Guidelines on Venture Capital. These Guidelines, to be followed by financial institutions, were expected to play a major and catalytic role in supporting domestic technology development.

11. Recent trade and investment reforms in India are expected to have great impact, following earlier policy statements and dispositions. These include the Industrial Policy Statement of 1980, which stressed competition in the domestic market, technological upgrading and modernization; the Sixth Plan, which emphasized the need for productivity; and the Seventh Plan, which pursued the technological and managerial modernizing of industry to increase productivity and improve competitiveness.

12. The New Industrial Policy (NIP) announced by the Government in July 1991, while emphasizing self-reliance and domestic technology development through investment in R&D, provided new dimensions to these terms. The Government was to pursue self-reliance, with greater emphasis on the ability to pay for imports through its own foreign exchange earnings. Domestic technology development was to concentrate on technologies for processes and products which were internationally competitive, in terms of quality and cost. It also emphasized the development of products and processes capable of generating competitive exports, or innovative developments of products and processes using the domestic resource base, and addressing both the domestic and export markets. The NIP also envisaged abolishing the monopoly of any sector or individual enterprise in any field or manufacture, except for strategic or military considerations, while opening up all manufacturing activities to competition. Foreign investment and technology collaboration were welcomed as they contribute to higher technology, increase exports and expand the production base[1].

13. Following the announcement of the NIP, several additional circulars and guidelines having a bearing on the subject of this report were issued. Two elements in these provisions could be considered of particular importance; they relate to: (a) concessions extended to the small-scale sector of the Indian industry, including the possibility for foreign investment in this sector; and (b) a new Foreign Investment Promotion Board, which was set up to deal with relatively larger projects, involving larger investments. In the new arena of liberalization, India is striving to create a conducive policy environment. In pursuit of this goal, the Government of India is currently working on a new Technology Policy Statement; it has accordingly released a draft document which is being discussed in diverse fora in the country. The draft includes sections on technology and society; technology and environment; skills; research, development and engineering (R & DE); resources for R & DE; necessary linkages;

---

[1] The NIP states, among others, that "With a view to injecting the desired level of technological dynamism in Indian industry, Government will provide automatic approval for technology agreements related to high priority industries within the specified parameters. Similar facilities will be available for other industries as well if such agreements do not require the expenditure of foreign exchange. Indian companies will be free to negotiate the terms of technology transfer with their foreign counterparts according to their own commercial judgement. The predictability and independence of action that this measure is providing to Indian industry will induce them to develop indigenous competence for the efficient absorption of foreign technology. Greater competitive pressure will also induce our industry to invest much more in research and development than they have been doing in the past. In order to help this process, the hiring of foreign technicians and foreign testing of indigenously developed technologies, will also not require prior clearance as prescribed so far, individually or as a part of industrial or investment approvals." (NIP, paragraph 28).

Concerning public enterprises, the NIP points out that "serious problems are observed in the insufficient growth in productivity, poor project management, over-manning , lack of continuous technological upgradation, and inadequate attention to R&D and human resource development...", and among the priority areas for growth of public enterprises, it indicates "...technology development and building of manufacturing capabilities in areas which are crucial in the long term development of the economy and where private sector investment is inadequate" (NIP, paragraphs 31 & 32).

policy implementation; and aspects concerning monitoring and review of the Statement.

2. India's overall R & D scenario

14. The R & D scenario in India today is characterized by a well-established science and technology infrastructure in terms of universities (approximately 130) and specialized national laboratories (approximately 200). Its stock of S & T personnel is approaching nearly three million and there are around 1,100 in-house R & D centres established by industry. The total R & D expenditure during the Seventh Five Year Plan (1985-1990) was about one per cent of India's GNP (approximately Rs. 140 billion). Out of this, 20 per cent was spent by the industry on R & D and 80 per cent by the Government, underlining the significant role of publicly-funded R & D institutions in India. Figure 1 represents the breakdown of the expenditure incurred by different agencies.

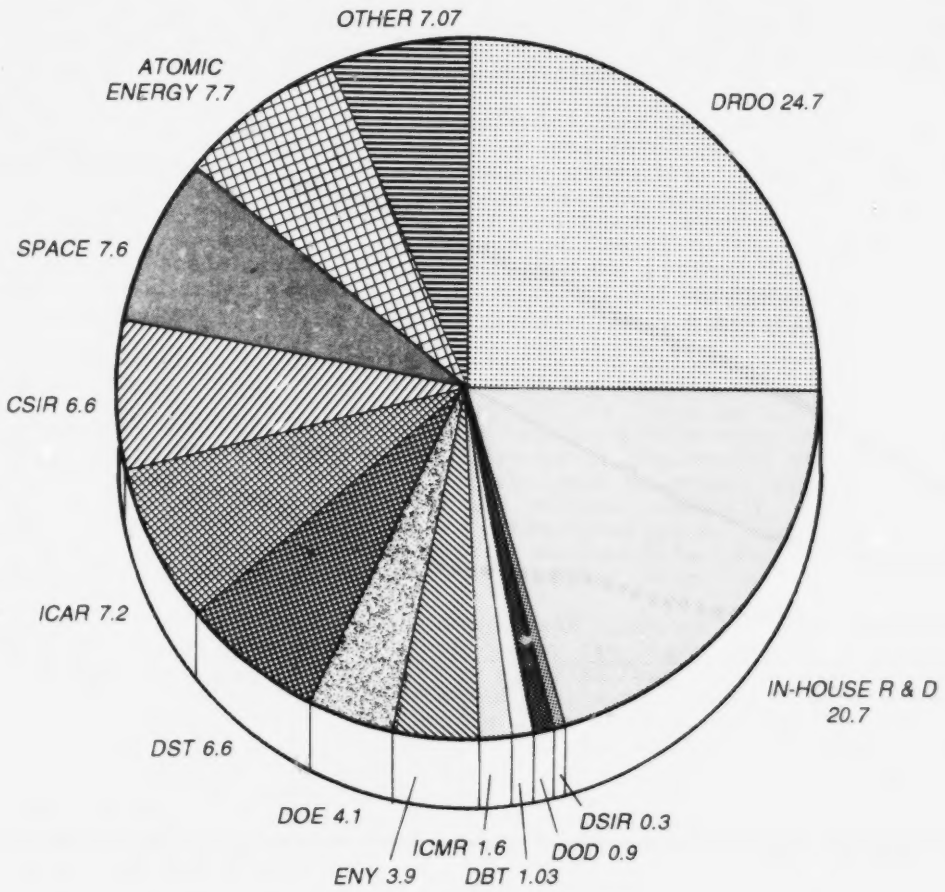
15. Some of the main features of the overall R & D setting in the country are presented below. Of the in-house R & D centres for industry in 1988, 100 belonged to the public sector, and the rest (approximately nine-tenths of the total) to the private sector. That year, the total expenditure on R & D in industry was about 0.7 per cent of the sales turnover of these companies. The in-house R & D centres currently employ about 60,000 persons, representing approximately one-fourth of the total R & D staff in India. Of this number, about 20,000 persons are qualified scientists or engineers, 2,000 of them with doctorate degrees. While industrial R & D expenditure has steadily grown during the last decade, for the country as a whole this spending has increased more rapidly. In connection with the growth of R & D centres in India, (see figure 2), on plotting the total number of R & D units against the year one finds that around 1985-86 the curve flattens off. Few new R & D units in industry have subsequently been established, perhaps owing to the withdrawal of some incentives for R & D during 1985-1986. This may also mean that Indian industry by and large does not yet fully consider technology innovation as an instrument of growth and competitiveness. Once competition sets in, and as companies have to innovate to create and secure a market position based on innovative processes or products, R & D is expected to increase. The Government can play an important role in creating the conditions for market-oriented innovation by industry.

16. A major part of industrial production in India is presently generated by medium and large-scale enterprises. In terms of sales turnover, approximately 50 per cent of estimated production in 1990-1991 is attributed to imported technology, and around 45 per cent to "domesticized" ("indigenized") technology. About five per cent of industrial production can be attributed directly to R & D.

17. In the late eighties, the payments made for technology imports increased more rapidly than the R & D expenditure by industry. During the Seventh Five Year Plan there was a 1:1 ratio of R & D expenditure to payments for technology imports, or 1:10 when R & D expenditure is compared to capital goods imported. Enhancing the R & D activities in industry would require strengthening several aspects, including those relating to the industry itself, the necessary S & T infrastructure, the links with financial institutions and engineering and consultancy organizations, and the approach to, and interactions with, the user of technology. An effective growth of R & D necessitates close interaction among the three groups basically making up the S & T infrastructure, that is, national laboratories and research institutions/associations, universities and in-house R & D centres of industry. Good examples of such linkages exist. They need to be diffused, as they can encourage the productive interaction of critical agents in the technology innovation chain, thereby maximizing the rational use of the existing skills and infrastructure.

Figure 1
R & D EXPENDITURE IN INDIA DURING THE 7th PLAN
1985 - 1990

APPROX. Rs. 140 BILLION

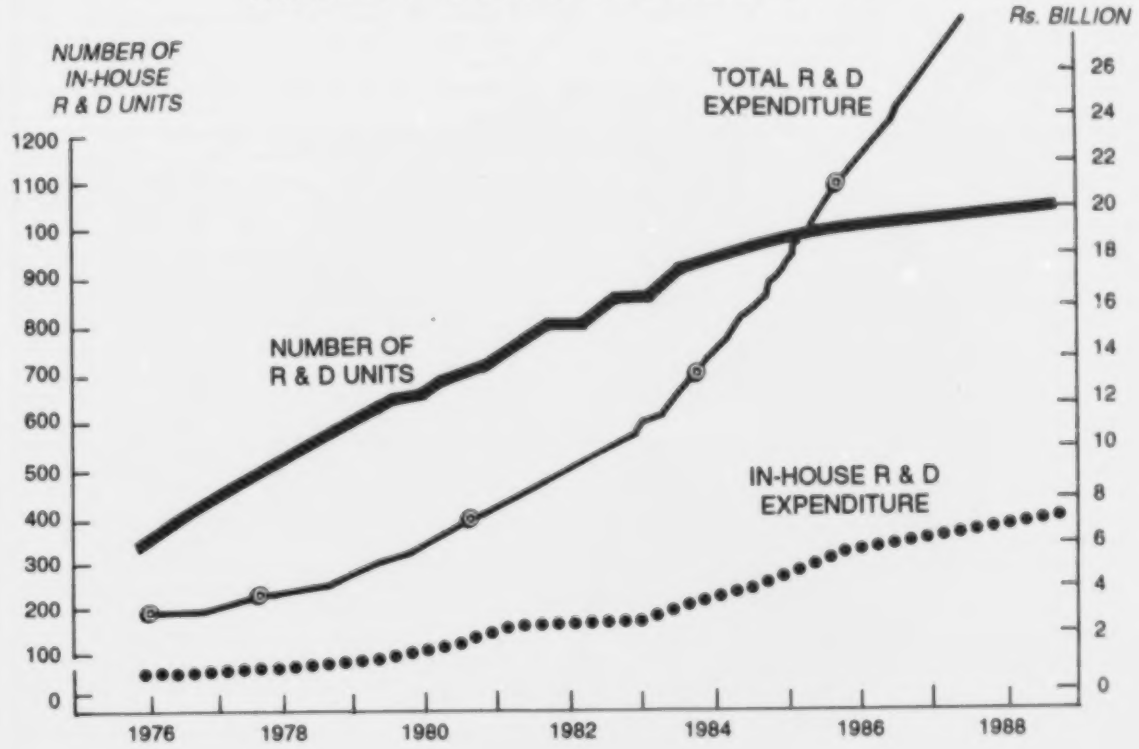


IN PER CENT

Legend:

CSIR : COUNCIL OF SCIENTIFIC AND INDUSTRIAL RESEARCH
DBT : DEPARTMENT OF BIOTECHNOLOGY
DOD : DEPARTMENT OF OCEAN DEVELOPMENT
DOE : DEPARTMENT OF ELECTRONICS
DRDO : DEFENCE RESEARCH AND DEVELOPMENT ORGANISATION
DSIR : DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH
ICAR : INDIAN COUNCIL OF AGRICULTURAL RESEARCH
ICMR : INDIAN COUNCIL OF MEDICAL RESEARCH
ENY : DEPARTMENT OF ENVIRONMENT
SPACE : DEPARTMENT OF SPACE

Figure 2
GROWTH OF IN-HOUSE R & D UNITS IN INDIA



B. The Indian chemical industry and the National Chemical Laboratory

18.Currently, the Indian chemical industry contributes approximately 40 per cent of gross industrial production, with an impressive annual growth rate of 10-15 per cent in the 1980s and increasingly important exports. These achievements largely result from a long process of technological development. Since NCL deals extensively with the chemical industry, the characteristics and trends of the Indian chemical industry are briefly examined in this section.

1. Main features of the Indian chemical industry

19. The Indian chemical industry began gaining momentum about 30 years ago, with the first petroleum refinery established in India in 1954. In the initial stages, practically all the plants were based on technology acquired from abroad, until domestic know-how and R&D began to significantly contribute to the growth of the chemical industry. This contribution has been considered particularly important in view of India's foreign exchange scarcity.

20. As regards infrastructural facilities, the availability of power and water for use by the industry is still unsatisfactory. A number of alternative feedstocks are available for the chemical industry, including naphtha, natural gas, ethyl alcohol based on agroproducts, etc. It seems that different plants producing the same chemicals from different sources is a unique Indian phenomenon[2]. Approximately 50 per cent of the chemicals in India are produced in the small scale sector. This sector does not possess the necessary technical, financial and other capabilities to increase its productivity and for handling waste management.

21. The changing trends in the industry are evident now. In the 1980s India entered into a consolidation phase, shifting from import substitution to export orientation. With the GDP growth rate in the 1980s at 5.5 per cent per annum, the chemical industry averaged an impressive growth rate of 10-15 per cent; the industrial growth rate was around 8 per cent. The export effort by the chemical industry has picked up momentum and the rate of growth has been high, at about 40 per cent, and in terms of actual volume, slightly exceeding one billion dollars. Segments like drugs and pharmaceuticals, dyes, agrochemicals and inorganics have done well in exports, whereas other areas have so far largely helped import substitution rather than export promotion.

22. The prices of chemicals and downstream products have been influenced by the high cost of raw materials, as well as by the imposition of levies and duties. The market price is often affected by changing import duties. Government policies clearly remain an important instrument for supporting the growth and stability of the chemical industry. Its delicate fortunes also relate to the purchasing power of the vast rural population, which depend on agriculture and the natural factors influencing it. If the monsoon fails for two or more successive seasons, the impact is immediately felt in the industries dealing with fertilizers, food processing and agrochemicals. The same holds true for other sectors, such as dyes, linked to the demands of the textile industry, as well as those concerning clothing for the population.

23. In the next 15 years investment in the chemical industry is expected to be approximately US $60 billion, not counting the downstream processing industries for plastics, elastomers, fibres, formulation of drugs and pesticides, etc. In several aspects, the Indian chemical industry will probably grow in a different way than in most countries during the coming decade, as illustrated by two key examples, fertilizers and synthetic fibres. Feeding a billion people by the year 2000 is a daunting task. India imperatively requires large investments in fertilizers over the next few years, and the nitrogenous fertilizer industry is

---

[2] Thus within a distance of 100 km from each other in Western India, one finds plants producing ethylene through a gas cracker (300,000 tons per year) and through molasses-based alcohol (25,000 tons per year).

expected to grow significantly, which is not the situation in the developed world. Also, the high pressure on land for food production will leave less land available for growing natural fibres, such as cotton. This calls for major growth in the area of synthetic fibre, including polyester, together with large manufacturing facilities, as well as intensive R & D to adapt the polyester fibre and filament to Indian tropical conditions.

24. Concerning the general direction of the Indian chemical industry as the year 2000 approaches, the industry is affected by many factors at work in the rest of the world. New developments will even affect so called "old" processes maximizing existing assets. The Bhopal disaster has rudely woken up everyone, and the demand for cleaner and safer technological processes will increase. Improvement in processes through "selectivity engineering" will continue, just as activities for reducing the demands on material and energy per unit of product will intensify. New concepts, such as that of the Combo Systems, where reactor and separator are considered as a single unit, will gain momentum. Similarly, the production of performance chemicals and materials is expected to introduce a new culture in the chemical industry, with a heavy emphasis on innovation and knowledge engineering. Demands on a function-oriented industry would probably follow with a package of products and services to be provided. Many of these trends are already emerging in the Indian chemical industry. In addition, the recent industrial policy by the Indian Government is expected to have a major impact.

2. The National Chemical Laboratory (NCL)

25. The National Chemical Laboratory (NCL), based in Pune, is a science- and knowledge-based research, development and consulting organization. It was established on January 3, 1950 by the Council of Scientific and Industrial Research (CSIR), which had as an important goal the creation of a strong science and technology base in the country and the development of research capabilities to support industry.

26. The first fifteen years of NCL were devoted to building up a competent scientific research capability in chemistry and chemical engineering. In the late 1960s and early 1970s, NCL conducted a considerable amount of applied research work while developing processes for industrial chemicals that led to import substitution. In the early 1980s, NCL shifted its emphasis to high-tech areas of catalysis, polymers, biotechnology and advanced materials. In the 1990s, NCL is aiming at promoting the commercialization and diffusion of its emerging technologies, as well as developing its competitiveness. In general, it could be said that during the past forty years NCL has evolved towards becoming an international centre of excellence in chemical sciences, engineering and technology. Today, NCL's staff comprises 1,100, of which 500 are scientists. Its annual budget in 1990-91 was Rs. 100 million. Out of this, NCL generated about Rs. 40 million through contract research and consultancy for industry and the Government. The laboratory has been responsible for the development of over one hundred processes, many of which are actively used in commercial production.

Chapter II

CASE STUDIES OF TECHNOLOGIES AND RELATED SERVICES DEVELOPED BY NCL

27. This chapter presents a selected sample of case studies of technologies and technology-related services developed by NCL, focusing on some of the lessons drawn from these cases. The mode of interaction with the industrial sector varies depending upon the nature and status of the respective technology, the size of the project, the strengths of the recipient industry and the available investments, and environmental factors, as well as the specific period in the history of NCL in which the technology was developed and transferred.

A. Xylofining technology

28. This case deals with new high-tech materials, namely highly competitive zeolite catalysts. It involves public sector undertakings, with the objective of selling a total technology package. The case resulted in the commercialization of a technology which, so far, had been the domain of major transnational companies. It also stresses the need for venture capital funding for innovations, which was non-existent in India until a few years back.

1. Elements of the case

29. The xylofining technology (xylene isomerisation) is particularly relevant to the production of polyester fibre, plasticizers, dyes and resins, which are increasingly important for the Indian economy.[3] By the year 2000, about one million tons of polyester fibre will be produced in India, which, along with China, will be the biggest producer in the world.[4] The critical role of xylenes in the production of the above-mentioned items underlines the importance of mastering the technology connected with xylene isomerization to obtain ortho-xylene and para-xylene separately. Based on its strong background in zeolite catalysts, NCL decided to focus on the development of an isomerization catalyst for this manufacture in order to improve productivity.

30. NCL had been involved in the development of commercial catalysts for a number of years. A few commercial plants based on NCL catalysts had been installed (such as dimethylaniline, by Sahyadri Dyestuffs). However, the advent of shape selective zeolite catalysts in the late 1970s spurred diverse areas in the petrochemical and petroleum-refining industry. With the objective of acquiring a basic capability in the synthesis of zeolite catalysts, testing, characterization, etc., NCL started work in the 1980s, a time when this area was dominated by multinationals such as Mobil. It was Mobil's ZSM-5 catalyst that formed the basis for NCL's explorations in this high-tech area. Later on, however, NCL's efforts were specifically targeted towards its own development of xylene isomerization and the generation of processes involved with new catalysts called encilites, which were based on the NCL technology.[5] Thus, at the laboratory level, NCL was able relatively early to develop a catalyst for xylene isomerization equivalent to the one used by Mobil.

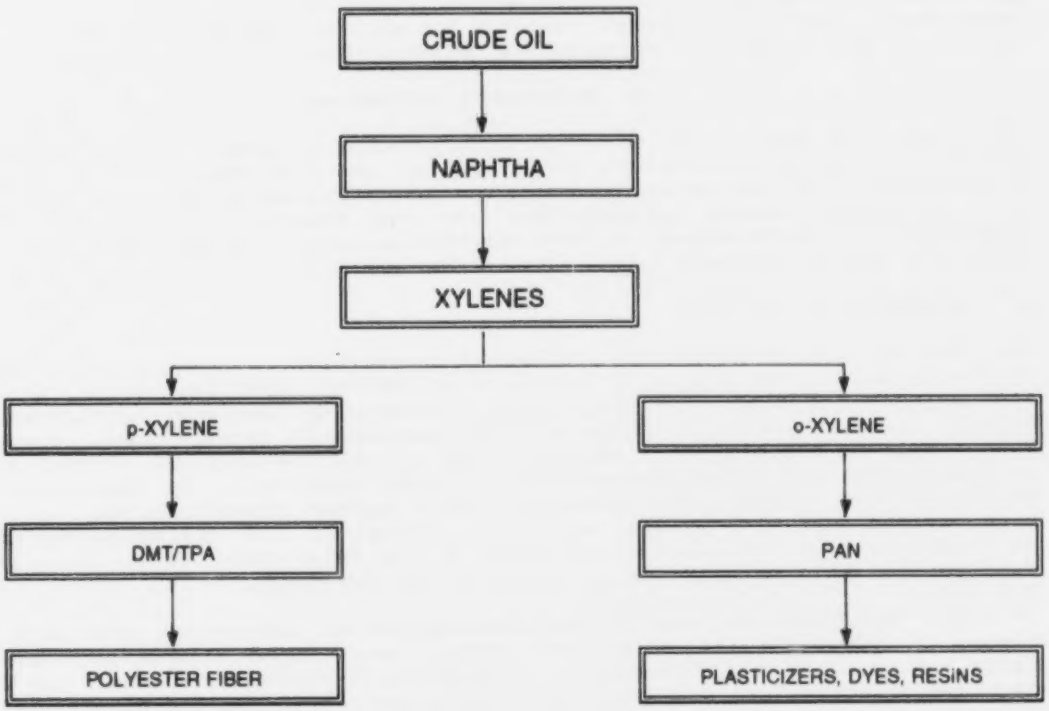
---

[3] The schematic diagram in figure 3 shows sources and applications of xylenes and the relative positioning of these chemicals in the final manufacture of polyester fibre.

[4] Two xylenes are involved in this production: (a) para-xylene and (b) ortho-xylene. Para-xylene is an important intermediate in the manufacture of purified terephthalic acid (TPA) and dimethylterephthalate (DMT), both of which are the basic raw materials in the manufacture of polyester fibre; ortho-xylene is also an important intermediate required in the manufacture of phthalic anhydride (PAN), which in turn is used as raw material for plasticizers, dyes and resins.

[5] The catalyst for xylene isomerization was designated as Encilite 1.

Figure 3
XYLENES: SOURCES AND APPLICATIONS



31. In 1981, the Catalysis and Adsorbents (CATAD) unit of the Associated Cement Company (ACC), a public limited company with a good track record in the manufacture of molecular sieves, joined hands with NCL. Considering zeolite-based catalysts as a natural extension of their business, ACC and NCL signed a broad memorandum of understanding for exploring a basket of catalysts with the objective of enabling the transfer of those with a potential for industrial application to the petroleum-refining and petrochemicals sectors. Of the various catalysts developed, the decision to focus on the one for xylene isomerization was taken in conjunction with the Indian Petrochemicals Corporation Ltd (IPCL), a public-sector company.[6]

32. IPCL, ACC and NCL entered into an agreement with the objective of finding a substitute for an imported catalyst, thereby reducing foreign exchange expenses as well as dependence on supply of a key material for the petrochemical sector. Under this agreement, IPCL agreed to provide feedstock from its plant for catalyst evaluation at NCL, as well as funds for the analytical equipment and chemicals required for the project. ACC agreed to fund the development from its own resources, since they intended to sell the catalyst to IPCL. The association and interactions among these companies proved constructive: ACC scaled up the process for synthesizing the catalysts developed by NCL; NCL tested the catalyst produced by ACC, and IPCL undertook the commercial plant trials.[7] The commercial plant has been running successfully. The Indian Chemical Manufacturers Association presented an award to IPCL for its role in the commercial use of this complex technology, and gave a special citation to NCL in recognition of the contribution made in the frontier high-tech area of catalysts.

2. Evaluation of results

33. A number of conclusions may be drawn:

(a) Encilite catalysts and their use in xylofining provided the first instance of the domestic development and use of high-performance catalysts in the Indian petrochemical industry. The risks involved in using this catalyst were high; failure would have meant a loss of production of para-xylene amounting to Rs. 1,000 million per year. This also would have meant the non-availability of this crucial input in polyester fibre production and that of other intermediates, thus affecting domestic availability of downstream petrochemical products in the Indian market. IPCL nevertheless risked using a domestic catalyst with full support from the Department of Petrochemicals in the Government of India.

---

[6] IPCL had set up the biggest petrochemical complex in India and was producing xylenes to the extent of 45,000 tons per year.

[7] The rapport between NCL and the catalyst development company was improved. As catalyst manufactures, ACC had to scale up the process for synthesizing all the catalysts developed by NCL in the laboratory, on a 100 gm scale, to the commercial scale of 1.5 tons. ACC had chemical engineers, who could do this scale up competently, and its CATAD unit was able to produce the required 1.5 tons catalyst for trials. The testing with the commercial feed was done by NCL. It was certified that the catalyst performed as per expectations. The commercial plant trials on this catalyst were started in June 1985 at IPCL. However, the conditions under which this catalyst operated were different from those pertinent to the original technology used by IPCL, and the plant in IPCL had to be modified. The plant trials continued until June 1986, for both high and low seventies. The performance of the catalyst was excellent under these conditions, and there was general confidence that the catalyst was indeed able to perform the tasks it had been targeted for. A major decision to load the catalyst after revamping was taken, so that about 90,000 tons of para. and ortho-xylenes could be produced. For this purpose, the encilite catalyst synthesized originally at NCL underwent modifications at the IPCL R & D Department. The new encilite catalyst manufactured at CATAD, which had been acquired by IPCL, was loaded in November 1989.

(b) IPCL has been producing a range of petrochemicals, using diverse types of catalysts which were previously imported. The confidence generated by the commercial manufacture and the successful commercial trials in 1985 encouraged IPCL to think that such high-tech materials could be manufactured in the country not only on the basis of cost competition but also on competition in performance. After assessing the possible requirements of catalysts in India and their export potential, IPCL decided to acquire CATAD, the manufacturing facility owned by ACC, which had originally produced the catalysts, and to enter in this new area of high-tech production. This has had additional spin-offs: The subsequent financial and technical investments made by IPCL in CATAD increased the latter's competitiveness and have led to the development of other catalysts, accordingly resulting in a significant boost of IPCL's own group involving catalyst R & D.

(c) Technology adaptation and improvement is a continuous process, particularly in the current competitive environment. As seen above, the catalyst developed by NCL, i.e., Encilite-1, successfully tried out in the commercial plant, had been a central achievement. However, in this high-tech area the displacement of catalysts by improved versions takes place rather rapidly and the continuous upgrading of Encilite-1 was necessary. IPCL decided to strengthen its own catalyst group and engage in a continuous and intensive effort of improving the catalyst. The result was in an improved version of Encilite-1, which was loaded during the actual commercial production commencing in 1990. IPCL's R & D catalyst group has also developed other catalysts for commercialization, not only within IPCL, but also in other plants.

(d) This case also proves the crucial role of venture capital. There are uncertainties about loading an indigenous catalyst: A considerable amount of resources could be involved in its loading and unloading, in the case of an interruption of production or in productivity losses should the catalyst fail to perform. The risk, in relative terms, may be small, but financial support at the right time can be decisive for the whole endeavour. In 1985, when the xylofining technology was commercialized, no such support was forthcoming due to the lack of venture capital companies in India, causing a certain delay in the progress of the project. Hence, availability of such financial support at that time would have made a considerable difference.

(e) The success of xylofining coupled with other successes in related technologies could be important for developing a capability in the total aromatics package in India. The blocks designating the individual processes and technologies involved are depicted in figure 4. In this particular package, the following technologies are already available within the country: naphtha reforming, aromatic extraction, and xylene isomerization.[*] The confidence gained from these experiences encouraged NCL, the Indian Institute of Petroleum and IPCL to agree to the joint development of the PAREX package. If this succeeds, India could emerge as a potential supplier of the aromatic technology package worldwide. NCL's xylofining technology is presently being offered as a complete technology package to new aromatic units in the country, against stiff competition from transnational corporations.

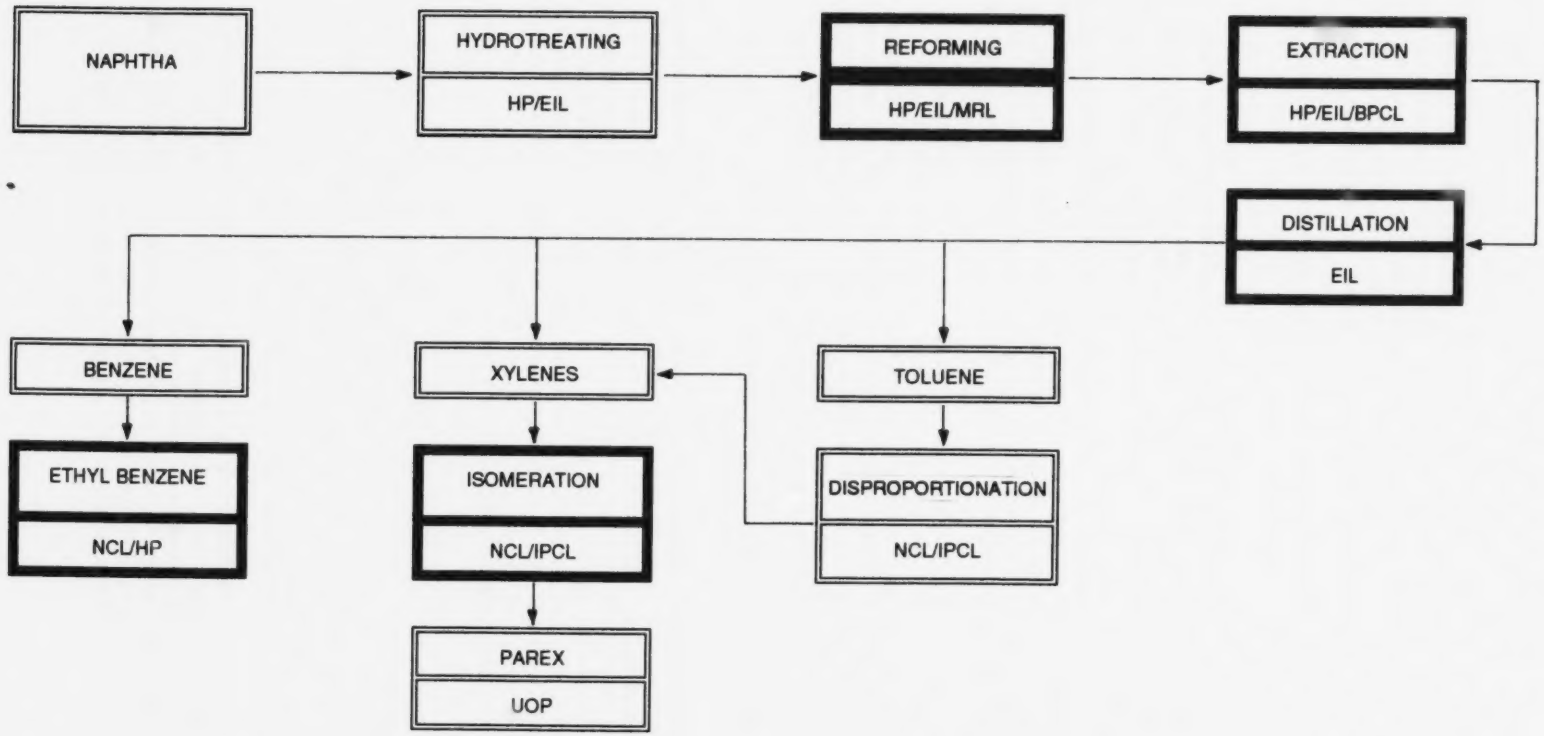
B. Albene technology

34. This case presents the results of the interaction between private enterprise and NCL, highlighting the fact that if innovation, competitiveness and entrepreneurship are kindled in a practical fashion, it is possible for industrial R & D partners in a developing country to generate the best available

---

[*] Others, not yet available, are important for owning the total aromatic technology package. They include, for example, a PAREX process, which relates to the separation of xylenes.

Figure 4
INDIA'S CAPABILITY IN THE TOTAL AROMATICS TECHNOLOGY PACKAGE



EIL: Engineers India Limited
HP: Indian Institute of Petroleum
IPCL: Indian Petrochemicals Corporation Limited
BPCL: Bharat Petroleum Corporation Limited
MRL: Madras Refineries Limited
HP: Hindustan Polymers
UOP: Universal Oil Products
NCL: National Chemical Laboratory

Process under development

Technology in which India has capability to offer turnkey plants

technologies. It also shows how solid performance builds up confidence and capacities which, in turn, act as catalysts for further joint and innovative ventures.

1. Elements of the case

35. Over the years, NCL's thrust has been on the development of catalysts, leading to novel processes expected to reduce raw material costs and energy consumption and to be more compatible with the environment. NCL has made a conscious effort to identify and occupy a market niche through a series of catalysts called "Encilites", an acronym for 'NCL Zeolites', although, transnational corporations have traditionally occupied a dominant position in this competitive field of high-tech catalysts. Albene (alkylation of benzene with alcohol) technology, which is commonly used for making plastics, is one example of NCL's technology development programme.

36. Until the end of the 1970s, the process for making ethyl benzene used corrosive and toxic catalysts; in 1980, NCL decided to develop a process which could avoid some of the drawbacks. A breakthrough occurred in 1982, when NCL filed the first patent on this process. In 1983, NCL contacted Hindustan Polymers (HP), a private company, for the commercialization of the process. A commercially-produced catalyst was loaded in the pilot plant of HP in 1985, and after one month's trial, an agreement for using the process on a commercial scale was signed with HP. Based on the feedback from pilot trials, the catalyst was modified, and two tons of commercially produced catalyst were thoroughly evaluated at NCL. Simultaneously, the existing HP plant was modified to suit this technology, and the new Albene process was commissioned in November 1989.

37. Presently, 12,000 tons of ethylbenzene are being produced yearly by HP using this process, which presents a series of advantages. The main advantages are the following: (a) It allows the direct conversion of alcohol and benzene to ethyl benzene, avoiding two processes, namely dehydration of alcohol to ethylene and bone drying of ethylene; (b) no corrosive or toxic catalysts are involved in the operation, avoiding environmental problems involved with acid sludge disposal, as was the case in using the old technology; (c) it ensures a 10 per cent reduction in the raw material consumption; and (d) its use can represent a reduction of 8 per cent in energy consumption. Compared to conventional processes, the cost reduction is considerable.

38. Since the process has been running successfully, two companies in India, M/s. Synthetics & Chemicals Ltd., Bareilly, and Polychem Ltd., Bombay, have expressed interest in licensing the technology. Discussions continue concerning the possible terms and conditions for horizontal transfer of technology. In addition, there exist possibilities of licensing in other countries with an important alcohol-based chemical industry, such as Brazil. The Indian Chemical Manufacturers Association gave a special award to Hindustan Polymers in 1989 for developing a novel and complex technology with a widespread impact on the chemical industry and the national economy. The Association also gave a special citation to NCL in recognition of its originality and creativity in developing a novel catalyst.

2. Evaluation of results

39. In examining the case, some of the following considerations arose:

(a) In the first place, the case of the Albene technology proved that it is possible for an Indian laboratory to develop a high-technology catalyst.

(b) The preference shown by some Indian firms in the 1970s for foreign technologies was due to the fact that they had been practised and proven abroad, even though many research organizations were ready to offer technologies at the laboratory or pilot-plant level. Foreign technology tended to come from a plant in operation, thereby reducing risks as well as the gestation period; its application usually starts bringing in profits

in a relatively short span of time. It was in this business environment that Hindustan Polymers took the risk and opted for a technology not proven abroad, a move that proved successful.

(c) Work in the area of high-tech catalysis requires a major team effort, not only when the catalyst is being developed but also when it is manufactured and used by industry. With the exception of collaborative R & D efforts in space, defence and atomic energy, examples of real team work are, in general, relatively few. From this point of view, the Albene technology development represents a step forward: Trust and mutual confidence were key factors in the partnership among such different organizations as NCL (in charge of the research and development), United Catalysts India Ltd. (the manufacturer of catalysts) and Hindustan Polymers (the technology user).[9]

(d) The broad strategies and the demands made upon scientific research in any given area change over time. With the current pressure on the chemical industry to develop environmentally sound technologies, R & D organizations also have to work towards the development of a 'safer chemistry for a better environment'. The development of the Albene process fitted perfectly into this strategy. The characteristics of this technology in terms of reduction of raw material consumption and energy consumption, as well as savings in capital costs, may ensure widespread use.

(e) The success encouraged Hindustan Polymers to look for other profitable products. The firm developed a chemical called paradiethylbenzene, based on a similar procedure, and even before the successful commercialization of the Albene technology Hindustan Polymers had signed a contract for manufacturing paradiethylbenzene with NCL. Currently, the laboratory and Hindustan Polymers are discussing the development of a range of other products.

(f) As in the case of xylofining, the question of developing total technology packages for competing internationally was considered. In this particular case, the total technology package available abroad is depicted in figure 5. Of the processes indicated, NCL has already developed technologies concerning (a) the fermentation of molasses to ethyl alcohol (Encilium); (b) the process for alkylation of benzene to produce ethyl benzene, (Albene) commercialized with Hindustan Polymer; and (c) the development of a catalyst for converting ethyl benzene to styrene, which has successfully been tried out by Polychem Ltd. in Bombay. This implies that with appropriate process engineering, the technology for the production of styrene will also be available; consequently, the total technology package for the conversion of molasses to styrene will become available for sale. In practice, this would tend to prove that the implementation of a grand plan for developing a total technology package is more related to the efforts and interactions of national laboratories with different public- and private-sector companies than to a drawing-board type of decision.

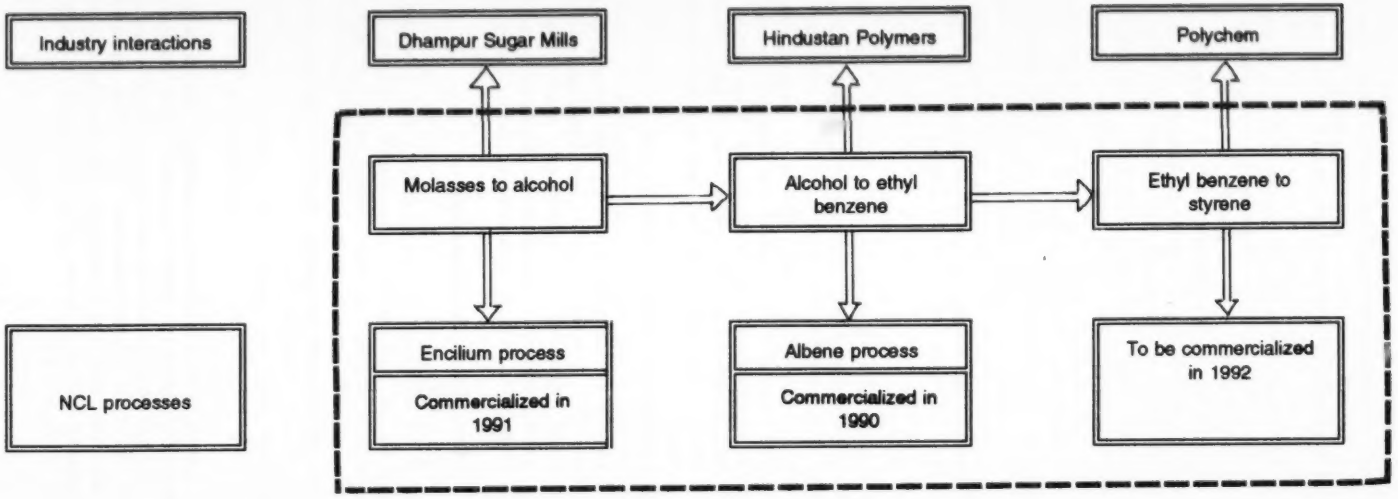
C. Encilium technology

40. This case demonstrates how the challenge presented by a specific technology import option was faced, and how a national academic research project could result in the development of a competitive technology, in continuous improvements of the process and in the adoption of novel and flexible marketing strategies. The case also demonstrates the positive inputs multilateral aid agencies can provide towards the success of R & D projects.

---

[9] The technology for the production of ethyl benzene from ethylene and benzene developed by Mobil and Badger Company (the novel Mobil-Badger process) won the Kirkpatrick Award in the USA, recognized as the highest international award for technology development in the chemical sector. The Albene process was the first process in the world to make ethyl benzene directly from alcohol, and the Hindustan Polymers plant was the first in the world to convert alcohol to ethyl benzene directly.

Figure 5
TOTAL PROCESS CONCEPT



1. Elements of the case

41. Ethyl alcohol constitutes an important feedstock for the Indian chemical industry. Fermentation batch processes existing in India formerly yielded about 220-230 litres of alcohol per ton of A grade molasses. After continuous fermentation processes available from abroad (e.g., Vogel Busch, Biostill of Alfa Laval, etc.) showed that this could be increased to 270-280 litres of alcohol per ton of molasses, the Indian distilleries became interested in these technologies. NCL began developing a world-class fermentation process for alcohol production, which is currently being commercialized. The phases necessary to achieve this increase are briefly described below.

(a) The first phase corresponded to the process of conventional immobilization of yeasts. In the late 1970s NCL's division of Biochemical Sciences commenced its work on the continuous production of ethanol by fermentation of molasses using an immobilized yeast.[10] The objective was to see whether this scheme could be used in industrial production. Ethanol was chosen since it formed part of an overall programme for ethanol production from cellulose, developed particularly after the oil crisis of 1973.[11] The process of immobilization of yeast on gelatine was perfected in two years, and it was decided to scale up the fermentation process in the pilot plant.[12] At this point the enterprise encountered problems. In fact, the picture looked grim from an economic viewpoint, and in December 1985 NCL decided to wind up the project.[13]

---

[10] This project subsequently became part of the UNDP supported programme on Bioscience and Engineering (Project No. DP/2ND/80/003/A/01/37 - September 1981 - December 1987).

[11] The concept of immobilization had aroused a lot of interest and considerable research was reported in the literature on the fermentation of sugars to ethanol. Not much work was reported using molasses as a raw material. It was therefore decided to take up work based on molasses. Many matrix materials were used by different groups, the most popular including sodium alginate and agar-agar. Work using gelatine as matrix material was not reported, and therefore gelatine was selected as the matrix material. It was also possible to achieve higher porosity of beads by using gelatine, which would have enabled higher loading of yeast cells.

[12] Laboratory columns (50-500 ml. size) had shown promising results. Fermentation efficiency of over 90 per cent was achieved at very high productivity of 20-50 grams ethanol/(hr)(liter) as compared to productivity of only 1 g/(hr)(liter) which was possible in the established practice of batch fermentation. Sterile molasses were used in these trials. When it was decided to scale up the fermentation process in the pilot plant, experiments were first carried out in a 30-liter glass column and subsequently in a 300-liter reactor. Use of gelatine-based beads had some inherent disadvantages, which came to be realized only during the pilot-plant trials. Gelatine being a very soft material, the beads disintegrated within a few days. The alternative products such as sodium alginate, agar-agar alumina etc. were tried as matrices but problems such as leakage of cells from the matrix, rapid deactivation of yeast and unacceptably high cost of immobilization remained unresolved.

[13] At this stage, when all the elements were reviewed, it was realized that for an inexpensive product like ethanol, a matrix-based process could never be viable. Other industrial applications of immobilization involved pharmaceutical and other products of high value where the cost of immobilization formed an insignificant part of the total product cost. To be economical in the case of ethanol, the support must have a long life or low cost. Looking at these constraints it was suggested that the process could become viable only if one could find a way to retain the yeast in the reactor without immobilization.

(b) The second phase corresponded to work on flocculating yeast. While the use of flocculent yeast[14] in breweries had been reported in literature, there was no real confidence that a flocculent yeast in a medium like molasses would be successful. Screening of the yeast to select a suitable flocculent strain would also have involved a lot of benchwork. At this stage, Professor Bu'Lock of the University of Manchester, a UNDP adviser for the project, suggested that a flocculent strain be tried out on molasses, which had worked very well on sugars. This method proved successful:[15] the process appeared technically feasible and economically attractive. A comparison of the new Encilium process with other competitive ones showed the superiority of the NCL process.

(c) The third phase relates to the interaction between NCL and industry on the scale-up and commercialization of the new process. Several parameters were also optimized and fixed during the pilot plant trials. At this stage, efforts got underway to sell the process to prospective clients from industry. Many parties showed interest, but some of them had reservations. Their concerns related to three technical points in connection with the scaling-up of the process: (i) Whether the yeast would behave in the same manner in a large reactor of 100-200 cubic metres (NCL's work had been carried out only in a 0.3-cubic metre reactor); (ii) Though the fermentation phase looked practical, industry found the requirements for the yeast growth phase stringent and difficult to apply in the existing set-up of a distillery; (iii) Air requirements during the yeast growth phase were considerable, thus adding significant costs to the process.

42. Though at first there was no great enthusiasm in industry about the Encilium process, NCL offered to implement it in two stages. It was suggested that a client industrialist set up a semi-commercial plant (that is, a pilot plant, the output of which could be sold) of 5,000-10,000 litres at its own distillery, and run it before going into full production scale. An entrepreneur, V.K. Geol of M/s. Dhampur Sugar Mills Limited, who was planning to set up a new grass-roots distillery, realized that if Encilium technology proved to be successful, then the capital cost would be much lower as compared to other competing technologies. In 1988 he agreed to cooperate with NCL.[16] A pending question concerned the high

---

[14] Flocculence is a physical property of the yeast cell wall. It was established that the kind of salts present in molasses will have a highly inhibitory effect on flocculence, and it was therefore expected that yeast would lose its flocculence once introduced into the molasses solution.

[15] The laboratory and pilot plant trials (in a 30-litre glass reactor) were conducted in 1987 using the flocculent yeast strain received from Prof. Bu'Lock. The yeast behaved remarkably well, even in molasses solution, and it was decided to take up the work on 300-litre reactor. Meanwhile many problems had to be tackled . These included mutation of yeast back to the non-flocculent variety, the adverse effects of CO2 gas recirculated to achieve agitation in the column, loss of flocculence after some time, etc. "Selection" growth technique was devised to solve the possible problems of mutation and the loss of flocculence. A continuous pilot plant run was then carried out in a 300-litre S.S. column type reactor wherein efficiency of 90 per cent and productivity of 100-litre of ethanol/(day) (m3 reactor) was achieved. The run was continued for 100 days and was then discontinued since the yeast had performed steadily. This ensured that the yeast would have a very long effective life. Now that there was no cost associated with yeast retainment in the fermenter, the process looked very attractive not only when compared to a typical batch process but also when compared to continuous processes available in the market, which were based on the use of a centrifuge for recycling the yeast back to the reactor.

[16] In order to attract him as the first customer, NCL had to offer a concession in licensing fees, which again was divided into four instalments, as follows: (i) 10 per cent on signing the agreement; (ii) 30 per cent after submission of the process manual, but before the commencement of

power requirements of the process; the necessary adjustments had to be worked out.[17] The resulting changes in the Encillium process presented several advantages. As the ethanol level was constantly maintained at five per cent, the growth of bacterial contamination was controlled at satisfactory levels; also, the power consumption diminished, and sugar was used 100 per cent efficiently. These improvements in the process were achieved after M/s. Dhampur Sugar Mills had purchased the know-how but before their plant was designed. Here is proof of NCL's direct interaction with the user industry and its willingness to improve on the basis of practical considerations, even after selling the process to an industrial client.[18] In April 1991, the M/s. Dhampur plant for 50,000 litres of rectified spirit per day was commissioned. NCL supplied all the basic engineering for the design and also checked and approved the final drawings. The plant is running satisfactorily.

43. In recent years, the Encilium process has generated considerable interest in the alcohol industry. Around fifty distilleries have approached NCL for details of the process. At present, there are approximately 160 distilleries in India producing around 700 million litres of ethanol per year. Most of these distilleries use a batch process and operate at an estimated efficiency level of 75 to 80 per cent. If they adopt NCL's Encilium process, India could generate approximately 100 million litres of extra ethanol from the same molasses. Existing distilleries could also be easily converted to the Encilium process. The modification cost is estimated to be around 3 million rupees for a distillery producing 30,000 litres per day, a cost which could be recovered in a year.

44. The know-how fee in this case was worked out by weighing the additional investment involved in modernizing the distillery and the monetary benefits accruing to a party on account of this modernization. Royalties were not considered applicable. At the same time, the strategy was to keep the applicable lump-sum fee to a reasonable level considering a multi-client sale possibility and piracy. The process was licensed to two parties.[19] NCL then deliberately stopped licensing Encilium to more parties until the commercial results became available.

45. Different modes of technology transfer were devised to suit the convenience of different types of clients. Private parties capable of undertaking the project on their own can today buy the process know-how and set up a plant with NCL's

---

demonstration runs at NCL; (iii) 30 per cent after the successful completion of trials on a semi-commercial plant; and (iv) 30 per cent after the successful completion of commercial plant trials.

[17] Passing air at the rate of 1 vvm required a compressor of the size of 300 HP. This was a very large power requirement indeed. Also, investment in this compressor was not required in the batch process and therefore it would have offset some of the advantages derived from the higher yield of ethanol. Another aspect was that the use of this compressor was required only for two weeks per year. It was therefore felt that air requirements during the growth phase must be brought down at any cost. It was then decided to try out yeast growth under fermentative conditions. This meant that both fermentation and growth should take place simultaneously and ethanol concentration should be maintained at around 5 per cent v/v. Aeration rate was also decreased from one vvm to 0.1 vvm. As one more finer improvement, initial inoculum charge requirement was reduced from 1 per cent to 0.1 per cent. This broke every rule of the classical yeast growth method; however if this led to the sole disadvantage of slower growth, then it suited NCL's peculiar process requirements hand in glove. It was found that yeast growth was excellent under these conditions.

[18] After running the semi-commercial plant with a 5,000-litre fermentor, M/s. Dhampur Sugar Mills scaled up the process to a 130,000 litre fermentor.

[19] Besides M/s. Dhampur Sugar Mills Ltd. (U.P.), the other one was M/s. Belganga Sahakari Sakhar Karkhana Ltd. (Maharashtra).

help and guidance for design -this was the model followed by M/s. Dhampur Sugar Mills Ltd. In Maharashtra, most of the distilleries are in the cooperative sector, and they prefer turnkey jobs. Since NCL is fundamentally an R & D organization, it can not submit a commercial bid for a turnkey job. NCL has therefore entered into a partnership with three engineering firms, which can make turnkey offers on the basis of the Encilium process - a tripartite agreement with the client and a project engineering firm. The process has now been licensed to four more parties.

2. Evaluation of results

46. The following points were made in connection with the above case:

(a) The option of foreign technology import in the area of ethyl alcohol, a critical element for the chemical industry, acted as a driving factor in NCL's development of a domestic and truly competitive process. The potential for sale of the Encilium technology is considered to be enormous. Out of a total 160 distilleries in India, it is estimated that at least 100 may acquire this technology, as it is domestic and cheap. This is in line with the New Industrial Policy, which supports agro-based products as well as those with a low import content. The multi-client sale approach required in this case necessitates a strong marketing effort and support in the technical follow-up. NCL formed a Task Force in July 1991, which is exclusively devoted to the sale of this technology on a multi-client basis[20].

(b) The case also shows that what appears to be a feasible process at the laboratory scale may not necessarily result in commercially viable technology. Major modifications were needed to achieve such an objective, based on a continuous assessment of the commercial viability of the process. NCL's invention of yeast growth under fermentative condition is what actually made the Encilium process possible. This came about because of the unconventional strategy used and the efforts by NCL in working with the technology users.

(c) NCL and other laboratories in India have been making use of UNDP-backed projects and support regularly. However, there are relatively few instances in which commercial processes and technologies have been developed as a result of such support. The input by the UNDP consultant facilitated the adapting of NCL's contribution to yeast strain to Indian molasses, as well as in developing a process where simultaneous yeast growth could take place under fermentative conditions[21]. The Encilium technology provides an example of UNDP support used in an imaginative way. It became evident that the technology could be adopted quickly and in a cost effective way in the existing distilleries.

---

[20] The project leader responsible for this is chairman of the Task Force and the convenor belongs to the Project Planning and Development Unit. Another member belongs to the team which developed the process, and another has previous background and work experience in a sugar industry research institute, and as a result, the right contacts with potential customers. Payments have been linked directly to the benefits that clients will realize. NCL decided to adopt different methods of technology transfers to suit different types of clients rather than having a rigid marketing and technology transfer strategy.

[21] Prof. John Bu'lock, of the University of Manchester, a UNDP consultant, suggested the use of the self-immobilizing yeast and provided the initial strain. See also UNCTAD, Utilization and Commercialization of United Nations System-funded R and D Results. Case Studies on the Indian Experience. (UNCTAD/ITP/TEC/20).

D. Metal replacement by polymeric materials in engineering applications

47. This case shows how a Government funding agency performed as a catalytic agent, while assisting in spreading the notion of change in private industry. This is also an example of how high-tech material for local applications, based on domestic needs, is introduced in a developing economy. Lastly, it shows the networking of different national agencies, promoting the optimal use of licence expertise and facilities, and contributing towards effective diffusion of R&D results.

1. Elements of the case

48. Polymers and composites are increasingly replacing conventional materials such as metals and ceramics in engineering applications. In large volume applications, such as in automotive parts, cost effectiveness is governed not merely by the cost of the materials, but also by an increase in productivity and design flexibility. Polymers compete favourably because of the inherent economics of plastic processing techniques, such as injection moulding, compression moulding and thermoforming. Their introduction simplifies the manufacturing process by reducing or eliminating assembly equipment and time, multiparty inventories and material handling problems.[11] Perspectives for use of polymeric materials are promising. In India, they have replaced conventional materials in consumer articles such as bottles, jerrycans, baskets, buckets, and toys. In the field of industrial articles, this has taken place in a limited fashion in products such as radio cabinets, cassette recorder housings, radiator fans and electrical switches. For precision and functional components, such as gears, pumps, impellers, bearing and springs, considerable efforts will still have to be made for their application and for related product and market development.

49. Realizing the importance of polymers and composites, the Department of Science and Technology (DST) of the Government of India initiated an R & D programme in 1975 for 'Newer Fibre and Composites'. The first phase of the programme (1975-80) focused on developing the technology for fibre reinforcement, whereas the second phase (1980-85) dealt with matrix resins for composites. In the third phase (1985-90), R & D efforts concentrated on the development of specific products of necessity to Indian industry. An integrated approach was favoured starting with systematic product identification, materials selection and the development of processing technology, tool design and product testing. At an early stage of the project formulation inputs were sought not only from research institutes but also from end users and production.

50. The NCL experience in developing and transferring the technology for a high-performance engineering plastic, namely polyphenylene sulphide (PPS), indicated that the first step for introducing engineering plastics in the country would be to inform and convince the potential users of the advantages of using plastic moulded components. The major users of engineering plastic components were the manufacturers of two wheelers, as these vehicles constitute the most important means of personal transport in India. In consultation with DST, discussions were carried out with M/s Bajaj Auto Ltd, the largest manufacturers of two-wheelers in Asia, for about a year prior to initiating the project. A tool maker/processor of engineering plastics was also involved in the project.[12] On the basis of the discussions, an operational approach was submitted for consideration to the industrial partners. It proposed to focus and develop technical competence in terms of a capacity for the selection of materials, product and tool design, and

---

[11] The potential of polymers and polymeric composites in replacing metals has been demonstrated in developed countries: The consumption of engineering plastics has already reached a level of one million tons in the USA. India is reported to be behind the advanced countries in this important area.

[12] M/s Kirloskar Kisan Equipment Ltd. was associated with the project beginning with the formulation stage.

processing involving specific relevant components for using high performance plastics.

51. A large number of the activities involved in developing moulded engineering components are summarized in figure 6. All these activities could not be carried out at NCL, therefore it chose to focus on only a few, as follows: (a) identification of key engineering components for the use of plastics; (b) preliminary calculations to assess cost effectiveness of the replacement of metal by plastics; (c) definition of quantitative performance specifications for the selected components; (d) recommendations concerning material selection with reference to performance targets, cost targets and processing conditions; (e) technical inputs concerning product design in plastics; (f) technical inputs concerning design of the injection moulding tools; (g) optimization of the moulding conditions with the selected polymers; (h) characterization of the materials and testing of the moulded specimens/components; (i) definition of quality-control procedures for both materials and moulded components.

52. Initially, two components were selected for development: a fan on a magneto rotor (7,000 RPM), representing a dynamic application, and a reed valve base, connected to a crank case, on one side and to the manifold on the other, representing a static application. Both are critical engine components." In both components, the material to be replaced was die-cast aluminum.

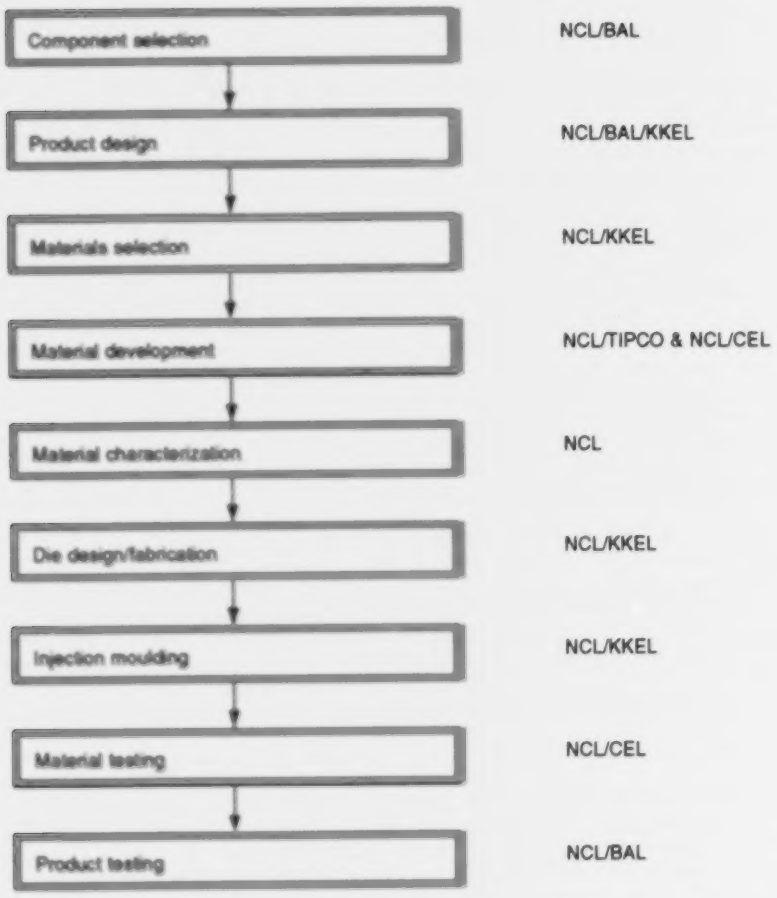
53. The major advantages in switching from metal to plastics include the elimination of a number of machining and assembling steps, with a subsequent cost reduction. Since the original components' weight was low (about 150 grams for the fan and 25 grams for reed valve base) there was no weight reduction. It was thought, however, that once confidence in using such critical engine components made in plastics had been established, a number of other components could be taken up for development. For example, large metal components, such as body panels, could be later on replaced by plastics, leading to a reduction in the weight of the vehicle of approximately 10-15 per cent. The vehicle field testing was concluded successfully and the moulded fans were successfully tested at 8,000 rpm, 10,000 rpm and 13,000 rpm without failure. Creep/indentation problems at bolting were eliminated. The frequency of impact failure in the "Drop Test" was reduced significantly by modifying the radius at the fin base. Continuous compounding of the special-filled grade PP was successfully completed at the production scale at TIPCO."

54. The industrial partners effectively joined hands with NCL and professionally and financially contributed to the project. The following facilities were used in this process: (a) tool design and fabrication facilities at KKEL; (b) product design facilities at BAL; (c) product testing at the BAL R & D centre; and (d) tool design/fabrication at KKEL. The project was successfully completed and commercial use of the two engineering plastic components on Bajaj Auto vehicles began in 1990.

" The fan is to be used for a scooter and the yearly requirement was estimated to be about 500,000 pieces for M/s Bajaj Auto Ltd.(BAL) alone. The reed valve base was initially to be designed for the moped and a new model of scooter, and a yearly consumption of 150,000 pieces was estimated.

" To this end, the injection molding conditions were optimized for a special reinforced grade of polypropylene (PP), developed in collaboration with M/s B.M. Thakkar & Co. Pvt. Ltd. (TIPCO). A series of molding trials were conducted for preparing samples of a molded rotor fan for product testing by BAL. On the basis of the results of product testing, design modifications were made in the product and die. Forty-five roter fan pieces incorporating the design changes, namely grooved metal inserts at bolt locations and improved radius at the fin base, were molded under the optimum molding conditions.

Figure 6
COMMERCIALIZATION OF THE NCL ROTOR FAN WITH BAL



NCL: National Chemical Laboratory - development agency
BAL: Bajaj Auto Limited - user industry
KKEL: Kirloskar Kissan Equipment Limited - processing industry
TIPCO: B.M. Thakkar & Co. Pvt. Limited - materials manufacturer
CEL: Century Enka Limited - materials manufacturer

2. Evaluation of results

55. In examining the above case, the following points could be made:

(a) The Department of Science and Technology (DST), a Government agency, identified the "Newer Fibre and Composites" as a new thrust area for R & D, and funded a corresponding programme. This initiative promoted the interests of private industry in the area; the industry subsequently joined the applications development programme.

(b) Contrary to a situation in which a large corporation may have all the R & D facilities and expertise, e.g., from the basic resin manufacture to the final product manufacture, in a developing country like India, a number of agencies need to establish effective collaborative arrangements if they wish to achieve the desired results.

(c) The impact of the project was both direct as well as indirect. A 20-25 per cent cost reduction resulted from the introduction of polymeric instead of metal components. A substantial saving could be made through the use of plastic rotor fans on 600,000 scooters. There were also other benefits. On the basis of the confidence acquired through this successful project, BAL prepared plans for replacing several other metal components in the scooter. The results were truly of a multiplicatory nature.

(d) The successful development of engineering plastic products in the area covered by the case has led other manufacturers of engineering goods to think in terms of replacement of metals by polymeric materials. NCL has accordingly entered into development contracts with two companies.

E. Pesticide technologies

56. This example shows how the setting of clear goals and consideration of the requirements of industry from the early stages of a project, as well as pooling the specialized competence of diverse R and D institutions, can contribute to effective results. It also highlights the importance of having an overview of all the steps necessary in R & D projects, including legal and institutional aspects related to market access of its results.

1. Elements of the case

57. The Indian pesticide industry is over three decades old. During the period 1966 to 1975, which witnessed the emergence of an intensive phase of agriculture and the start of the Green Revolution, the consumption of pesticides and fertilizers increased threefold. After initially importing pesticide formulae, the country developed technical competence in this area: After Japan, India is currently the second largest manufacturer of basic pesticides among South Asian and African countries. Most of the manufacturing units established in the 1970s and 1980s are based on domestic technology. India is almost self-sufficient, although it imports some of the newer and more sophisticated pesticides. At the level of technological development, the challenge of the demand for pesticides in India, both for agriculture and public health, has largely been met through CSIR contributions.

58. In 1971, the Government of India set up the National Committee on Science & Technology (NCST) with a charter to prepare a comprehensive S & T plan for all the vital sectors of industry. The Pesticides Planning Group of the NCST was made up of leading experts from CSIR, industry and representatives from operating ministries, the Directorate General of Technological Development and the Planning Commission. The Group submitted a status report highlighting existing status of the pesticides industry in India, technological gaps/needs, recommended areas for technological development, necessary R & D inputs and estimation of benefits to the nation from commercializing the developed technologies. The status report was prepared with the active collaboration of NCST.

59. The NCST status report, submitted in 1973, formed the basis of a

comprehensive research programme on pesticides undertaken by CSIR laboratories. The participating laboratories and the role and nature of their work is given in table 1. After intensive debates with experts at the national level, the Group identified a series of short-term (3-5 years) and long-term projects (5-10 years) for R & D at the national laboratories. The details are given in tables 2 and 3.

Table 1
Pesticide R & D in CSIR Laboratories

Laboratory/institute	Nature of work
National Chemical Laboratory, Pune (NCL)	Research & development, design and engineering of commercial plants
Regional Research Laboratory, Hyderabad (RRL-H)	Research & development, design and engineering of commercial plants. Generation of toxicity data.
Regional Research Laboratory, Jorhat (RRL-J)	Research & development, design and engineering of commercial plants.
Central Food Technological Research Institute, Mysore (CFTRI)	Developments of techniques for storage of grains and seeds and generation of toxicity data
Industrial Toxicology Research, Lucknow (ITRC)	Generation of toxicity data
Central Drug Research Institute (CDRI)	Generation of toxicity data

Table 2
Short-term R & D projects in CSIR Laboratories

Project title	Implementing organization
Organophosphorous pesticides	NCL, RRL-H
Endosulfan, aldrin, etc.	NCL
Lindane, high y-BHC	CFTRI, NCL
Kelthane	IARI*, NCL
Methoxychlor	RRL-H
Tetradifon	RRL-H
PCNB	NCL
Benomyl	RRL-H
Vitavax	IARI, NCL
Hinosan	IARI, NCL
Paraquat	RRL-H
Dalapon	NCL
Nemagon, Nemex	RRL-H
Formulations	IARI

* Indian Agricultural Research Institute.

Table 3
Long-term R & D projects in CSIR Laboratories

Project title	Implementing organization
Synthetic juvenile hormones	NCL
Mode of action of insect hormones	IARI
Herbicides based on phytotoxins	Nimbkar Research Institute, Phaltan, Maharashtra
Neurotoxins of insects	RRL-H
Natural and synthetic pheromones	RRL-H, NCL
Insecticides from plants	CSIR Labs.
Pesticide-polymer combinations	NCL
Synthetic pyrethrins	NCL, IARI

60. Work on the development processes of critical agro-chemicals began as a top priority in several CSIR laboratories, especially at NCL, Pune, at the Regional Research Laboratory, Hyderabad and at the Regional Research Laboratory, Jorhat. A formal dialogue and interaction with leading pesticide industries was already established at the planning stage, since two of them were members of the Pesticides Planning Group. According to the demands of the industry, the original list of the items was adapted. Many of the projects launched resulted in operating manufacturing plants during the last decade, and have had a sizeable impact on the Indian agro-chemical industry. In particular, it may be noted that technologies for many sophisticated pesticides belonging to the organophosphorous group have been successfully transferred from the laboratory to production units.

61. One problem is worthy of mention: While national laboratories were busy developing and scaling pesticide technologies to the production and commercial levels, no thought was given to the regulatory requirements under the Insecticides Act of 1968. According to the Act, data on the toxicity and bio-efficacy of pesticides had to be submitted before registration for production and sale. As a result, the transfer of technology and the commercialization of R and D results was delayed by two to three years.

62. After completion of their activities under the NCST plan, the laboratories continued to work on a new generation of pesticides, such as synthetic pyrethroids, plant and insect hormones and growth regulators, and insect pheromones, as well as on improved formulae and delivery systems. They have thus been able to respond to changes in technology and external environment. We shall illustrate this with two examples from NCL. As a result of the Bhopal disaster, companies worldwide started looking into alternative methods for manufacturing carbamate pesticides by a non-MIC/non-phosgene means. NCL was one of the first laboratories in the world to have developed an alternative process for commercialization by which it collaborates with an Indian company. This process has in the meantime been patented in the United States.[24]

63. Plant hormones have already revolutionized agriculture. One of the recently discovered products is brassinolide, a plant hormone that can double the growth of food plants by both cell elongation and cell division. Only recently have chemists been able to isolate, identify, and then synthesize

---

[24] The US patent number is 4,967,007; the Indian company, Excel Industries Ltd.

this valuable substance, which is expected to contribute to the increase of food supply. Synthetic chemists are working on several close derivative analogues of brassinolide, and agricultural scientists are evaluating them in the greenhouse production of potatoes, soybeans and other vegetables worldwide. In the meantime, NCL has developed a complete process technology for manufacturing brassinolide and has entered into an agreement with a private company (Godrej Soaps Ltd.) to scale up the production process. This may end up with India being a primary commercial source of this product.

2. Evaluation of results

64. Two major conclusions were drawn from this case.

(a) Government-funded R & D laboratories have in certain instances failed to achieve results due to a lack of focus in their activities and a gap between such activities and the actual requirements of potential clients. The case of pesticide development shows that NCST assisted in goal-setting and in directing the efforts of the scientific community, through the recommended priorities. The case also points out the critical role of the debate engaged at an early stage with experts connected with industry in all its aspects, viz. R&D, planning, organization, production and marketing. This is because technological development has to be market driven and in isolation, scientists have generally no feel for the requirements of the market.

(b) The case represents an example of CSIR laboratories having worked on a coordinated and targeted programme by pooling all their specialized skills and strengths. However, the delay in the effective commercialization of the R & D results not only suggests that project management should consider every innovation aspect, including those of a legal and institutional nature, but also stresses the fact that while the R & D side of operations is critical, much thought should be given to paving the way and planning ahead for commercialization, that is, efforts must be directed toward combining technical competence and market knowledge. Once a capability has been developed in one particular area, the competence generated makes it possible to respond to rapid technological, environmental, industrial and regulatory changes.

F. Chlorosilane technology

65. This specific case shows how a modern technology can be developed with inputs from an R & D organization, matching process engineering, and the partnership of a private firm ready to take risks.

1. Elements of the case

66. Chlorosilanes are used in the manufacture of silicones, which have widespread applications in a number of key industries. The technology for the production of chlorosilanes was originally closely guarded by a few multinational companies. In 1970, NCL initiated an exploratory project on methylchlorosilanes and set up a powerful interdisciplinary team comprising chemical engineers, process development engineers and inorganic chemists working on laboratory scale.

67. Some of the distinguishing features of the process developed by NCL were as follows:

(a) Instead of using imported metallurgical grade silicon of 97.5 per cent purity, as in other processes, it could be based on indigenous ferro-silicon, containing 60-85 per cent silicon, enriched through a chemical treatment to 93-95 per cent silicon content.

(b) Instead of using copper as catalyst, it used cuprous chloride, deposited on the silicon surface after reduction to copper; antimony and zinc were used as promoters.

(c) In following the commonly used direct synthesis through which methyl chloride directly reacts with silicon to form methylchlorosilanes, the NCL process introduced the stirred fluidized-bed reactor, a pioneering effort at that time.

68. M/s. HICO Products Pvt. Ltd., Bombay (HICO), a medium-scale, profitmaking chemical firm, was selected as a partner for up-scaling the process to the commercial production stage, HICO had already been producing silicone products from imported methyl chlorosilanes.[27] A collaboration agreement was signed by NCL with HICO for further developing the technology for silicone intermediates, whereby HICO paid for the R & D work to be carried out by NCL. Following the agreement, HICO successfully set up a pilot plant with a capacity of 300 kilograms per day at Belapur in Maharashtra, based on basic design data from NCL and detailed engineering designs from Humphreys and Glasgow Consultants Ltd., Bombay. The pilot plant commenced operation in January 1981 and was used to optimize the process and verify design parameters by taking a number of batches at various scales. The product conformed to international specifications and was used by HICO for making silicone products - emulsions, greases and resins. The evaluation of data generated from the pilot plant with respect to input consumption, process parameters, recovery efficiencies and quality at various stages of production confirmed that the process was on a par with any other available from abroad. HICO was very much enthused by the success, especially since the chlorosilane technology had not yet been transferred to any Indian party, it would be the only company in India (and India the second country in Asia, besides Japan) to have the technology to produce world-class chlorosilanes.

69. HICO thus decided to set up a large-capacity plant for manufacturing methyl chlorosilanes based on the NCL/HICO technology. The detailed project engineering for the commercial plant was handled by Humphreys and Glasgow Consultants Ltd., Bombay. In 1982 a commercial plant for the production of 1,000 tons per year was set up at Kharsundi in Maharashtra. This represented an investment of about 75 million rupees, which was probably one of the highest investments by a private company in domestic technology at that time. The products produced by HICO were found to conform to international specifications; raw materials consumption and the product mix composition norms were also comparable to international levels (see tables 4, 5 and 6).[28] In 1983, HICO was awarded the prestigious Indian Chemical Manufacturer's Association Award for the development of Forward Technology, and NCL was given a special citation for its contribution to the development and successful transfer of technology in this challenging area.

70. At that point, some of the foreign manufacturers showed an interest in the transfer of their technology to India. This led to a number of foreign collaboration applications seeking approval to manufacture methylchlorosilanes. In August 1982, applications of eight parties to manufacture chlorosilanes were at different stages of consideration by the Government.

---

[27] HICO had an impressive record of industrial R & D: Its expenditure on R & D was 2.5 - 3 per cent of turnover, one of the highest for an Indian industry. It manufactured a large range of chemical products based entirely on indigenous technology developed in-house or acquired from national R & D institutes. Its product range included many import substitutes and items being produced in India for the first time, including methyl chloride, one of the two main raw materials used in the manufacture of methyl chlorosilanes.

[28] The principal components of the product mix from the reactor are dimethyldichlorosilane (DMDCS), methyltrichlorosilane (MTCS), trimethylchlorosilane (TMCS) and methylhydrodichlorosilanes (MHDCS). DMDCS is the fraction used for the manufacture of most silicone products; other fractions have minor applications.

Table 4
DMDCS purity (using GCL) from different technologies

Item (percentages)	Dow Corning	Bayer	Rhone Poulenc	Wacker Chemie	HICO	ICI
DMDCS	99	99.6 - 99.8	87.7	99.8	99.89	99.8
TMCS	0.02	0.02	0.05	0.02	-	-
MTCS	0.5	0.05 -0.2	0.1	0.05-0.2	0.11	-
Impurities	0.48	0.1 -0.2	0.1-0.2	0.1-0.2	-	-

Table 5
Raw materials consumption/ton of chlorosilanes

Items	Consumption in kilograms	
	HICO	Others
Silicon metal	300	280-320
Methyl cloride	980	950-1060
Catalyst	15	15-30

Table 6
Comparative figures for product-mix composition

Component	Yield (%) based on technology from:	
	HICO	Others
DMDCS	70-75	65-70
MTCS	15-21	15-20
TMCS	2-6	3-5
MHDCS	1-4	3-8

71. In general, the horizontal transfer of technology from one commercial unit to another non-associated unit has been a rarity in India. In the present case, NCL had stipulated from the beginning that commercial level technology should be available for transfer to others through a government-owned technology transfer company, the National Research Development Corporation (NRDC). By 1983, NRDC was offering a commercial technology package along with guarantees on a level with other international licensors. NCL, HICO and NRDC objected to the import of technology on the basis of the Technology Policy Statement (TPS) formulated that very year. The Government appointed expert committees to review the comparative merits of the Indian and foreign technologies; based on their technical opinion, the applications for foreign technology imports were rejected. While NCL and HICO appeared to be succeeding in protecting their technology, two major problems cropped up: a runaway escalation in the prices of raw materials, and Government policies changed with regard to excise duties and items to be freely imported, making the import of chlorosilanes much cheaper than the HICO product.

72. In March 1985, the Import-Export Policy announced for the period April 1985 to March 1988 placed methyl chlorosilanes under the 'Open General License' (OGL) category. This had the impact of promoting import by actual users and export houses against licenses. The policy also placed "silicone compounds/fluids/oils/resins"in this category. All these items were being produced in India at that time. An indigenous producer like HICO was to compete with international companies able to sell their chlorosilanes at lower prices, e.g., due to lower cost inputs and economies of scale.

73. HICO, operating at mere 30 per cent of plant capacity, had by then accumulated tons of stock of its products, an amount that a medium-sized company could ill afford to hold. HICO was unable to continue the production of chlorosilanes for commercial reasons, and thus was forced to close its chlorosilanes plant. Since there have been no further attempts to set up a production facility in India, chlorosilanes are being imported.

2. Evaluation of results

74. Two principal conclusions were drawn:

(a) This case describes, in the first place, an important domestic technological innovation effort which incorporated the highest levels of skills in science and engineering. It also included an exemplary cooperation arrangement with a middle-sized company for the actual commercial application of the generated domestic technology.

(b) The case also raised questions which go beyond the scope and role of an R & D institute in its efforts to accumulate specific technological capabilities and to use these in the effective application for production. Of particular importance among these is the question of the revised functions to be performed by the different economic actors involved in technology innovation in the new international economic environment, and particularly the role of the government in creating the required supportive conditions.

G. Consultancy services

75. The export of NCL consultancy services to China demonstrates that developing countries can have the necessary expertise, human resources and skills in important areas, and that they can cooperate among themselves while assisting each other in solving science and technology problems, as well as sharing the experience gained.

1. Elements of the case

76. As seen from the above illustrations, NCL has accumulated considerable expertise and technological know-how. The professional capabilities of approximately 500 specific collaborators cover all branches of chemistry, chemical engineering and allied disciplines. More than a third have doctorates, and many of them have undertaken post-doctorate research in prestigious universities in the United States, Europe and Japan. Some of NCL's researchers have also worked for large chemical companies such as Dupont, UOP, Owens-Corning, Petrofina, Ciba-Geigy, Hindustan Lever and Indian Petrochemicals, before joining the laboratory. Many of NCL's senior scientists have also been called on by the Government of India to undertake special assignments related, for example, to planning and the development of various sectors of the chemical industry; some have participated as members of the scientific advisory committees of departments related to chemicals, petrochemicals and fertilizers, and still others have been members of the Science Advisory Committee to the Prime Minister and the Cabinet.

77. About ten years ago, NCL decided to offer its pool of expertise to industry on a consultancy basis. While having entered the consultancy field a little later than other companies, NCL created a niche for itself, particularly owing to its rare combination of diverse disciplines, all under

one roof, offering a variety of services. These include the following: (a) process simulation, optimization and energy conservation; (b) process improvements and modernization studies; (c) process design and engineering; (d) research and technology management; (e) project planning and development; (f) product, application and market development; (g) technology search, evaluation and selection; and (h) various analytical and other technical services. NCL has already provided consultancy services in the above areas to a vast array of clients.

78. More recently, in accordance with Government policy concerning the promotion of services exports, NCL management decided that in addition to the selling of processes NCL shouls also concentrate on knowledge-based products, including software and consultancy services. This represented a major departure from the past. Along these lines, in 1990 NCL submitted a bid for consultancy in China within the framework of a global enquiry for a World Bank assisted project.[29] NCL competed for this assignment with world renown companies such as Arthur D. Little Inc., Chem Systems Inc., and International Development Planners. The Jiangsu Petroleum & Chemical Industry Department, in consultation with the World Bank, selected NCL to provide the consultancy services. NCL's record in R & D management, technology development and industrial interactions may have contributed to this. This was the first such bid from an Indian national laboratory.

2. Evaluation of results

79. The following conclusions can be drawn from this case:

(a) Competing and winning contracts such as the one mentioned above in international competition with some of the best consultants in the world has promoted a competitive culture at NCL. Its staff has learnt a lot through preparing bids in a professional way and by interacting with institutions such as Exim Bank and World Bank. It is now clearly understood that to compete internationally, everything has to be of an uncompromisingly high quality, including the supporting documents.

(b) The contacts generated through the international consultancy project led to a number of spin-offs. The visit to China of a team of consultants from NCL resulted in further cooperation opportunities, including the transfer of technology from China to India for a specific catalyst, various forms of S & T collaboration between NCL and Chinese R&D institutes, and the possibility of other consultancy assignments.

(c) NCL's consultancy work for China generated broader interest: The visit of the NCL team was followed by missions from the Indian chemical industry, the Science and Technology Department, CSIR, etc., which explored further cooperation between India and China. In its activities, NCL brought together enterprises from both countries for a specific technology transfer.

(d) The success of the assignment in China has led NCL to seek opportunities for offering its services in other developing countries with the assistance of multilateral aid agencies such as the World Bank, Asian Development Bank and African Development Bank. A contract with support from USAID is to be finalized for a study in Africa.

(e) In general, this case led NCL to believe that making Indian expertise

---

[29] The Jiangsu Provincial Government in China had applied to the World Bank for a loan of US$ 100 million to develop its chemical industry, including associated R & D institution-building aspects. The consultancy services were required for strengthening the research and development capabilities of two chemical R & D institutions, namely the Nantong Synthetic Materials Research Center (for engineering plastics) and the Suzhou Research Institute of Chemical Industry (for fine chemicals).

available in the domain of science and technology for development could help other developing countries in solving problems concerning food, health, shelter, etc., as well as in setting up the necessary S & T infrastructure; therefore technological cooperation could be promoted among developing countries in a highly critical sector.

H. Beyond the cases

80. As seen above, the cases described reflect an attempt by NCL to draw lessons applicable to future work. Together, the cases provide an illustration of what are mostly success stories in NCL's experience. Not all of its R & D ventures have reached the commercialization stage without problems, as is demonstrated in the case of pesticide technologies, where attention was mostly paid to the R & D side of operations, while legal requirements, important for commercialization, were only considered a posteriori. Of particular interest is the way in which insights gained from past experience could be put into practice - e.g., how to promote and strengthen contacts and linkages with users and producers. This is examined in the following chapter.

Chapter III

RESEARCH & DEVELOPMENT FOR COMPETITIVENESS

A. Prospects in a new economic environment

81. In India, as in most developing countries, policies have recently been set up which are market-oriented and open to trade and foreign investment. In the new world economic setting, characterized by growing internationalization of production and importance of trade, technology generation can no longer escape global considerations. At the respective national levels, a major question relates to how to provide a stable macroeconomic environment, a conducive regime for foreign entry, and liberal trade policies, with investments in human capital and technology support institutions to encourage continuous upgrading of industrial activities[30]. National investment in capability development ranges from investment in human resource development and technological infrastructure to policies and measures for selectively promoting industrial and technological development. The externalized purchase of foreign technologies and the focusing of efforts on areas of future comparative advantage has acquired renewed importance in this context, in which the role of economic actors, including the government, is being redefined.

82. NCL's achievements have been reexamined in the context of the emerging scenario in India, as the economy opens up. At this juncture, of particular significance to Indian R & D is the fact that products will have to be internationally competitive in quality and cost in order to compete both locally as well as globally, and that state-of-the art technology, particularly for the chemical industry, has not entered the country, a situation that is likely to change as property rights are strengthened. It is felt that while in the past R & D laboratories focussed on the needs of an insulated India, R & D will now need to increase its ability to contribute to global innovation. NCL is one of the publicly-funded R & D laboratories which can do so and thereby actively contribute to the emerging scenario, both in India and abroad. As seen above, NCL has been developing a customer focus, that is, it has been aiming at commercial application of industrial research rather than at scientific research for its own sake, which has not often been the case with many research institutes in developing countries.

83. The New Industrial Policy, by abolishing licensing in many sectors and opening up the economy to foreign investment and technology, represents an important landmark in India's policy framework with implications for investment in industrial R & D. A shift in industrial policy from a protected environment to a progressively deregulated market-driven economy necessarily implied a period of readjustment. In the short term, the nature and quantity of foreign investment flows as a result of the new policy have been uncertain, and a possible initial decline in major new industrial investments could be expected, except where commitments have been made. Accordingly, available resources for R&D support and R&D receipts from industry for a laboratory like NCL, at least in the immediate two to three years, would be limited. This trend could be expected to be partially offset by import substitution projects which are efficient. Towards this end, NCL intends to be highly selective and to favour products with opportunities for innovative chemistry.

84. Upon the progressive adjustment of the Indian economy to a competitive economy, in the medium and long term the prognosis for domestic R&D looks bright. Experience has shown that innovation thrives in an environment which rewards risk takers. From an intermediate standpoint, foreign technology could be expected to come into India mainly attracted by those areas where manufacturing provides a foreign company with either cost or export market

---

[30] UNCTAD, The Interrelationship between Investment Flows and Technology Transfer: An Overview of the Main Issues, (UNCTAD/ITD/TEC/1).

advantages. In this context, the Indian chemical industry, barring some exceptions, faces a situation characterized by: (a) the large size of domestic markets for chemicals with yet unsatisfied demands; (b) the high cost of inputs such as energy, feedstocks and raw materials, and the dependence on a significant number of raw-material imports; and (c) the non-intensive nature of chemical industry labour, where the basic advantage of India's low labour cost is largely irrelevant. With increasing competition, the main options available to the Indian chemical industry have been considered to be from the domestic market, or to upgrade its products, processes and services through applying domestic R&D.

B. Identification of market opportunities for NCL's activities

85. At NCL, an intense process of reflection took place within weeks of the announcement of the NIP. The necessary directional changes for responding to the challenge posed by the new policy setting were first identified and analysed. The ensuing internal policy decisions are now being implemented as part of the recent Five Year Plan drawn up by the laboratory. On the basis of this initial response, an analysis was made of the opportunities for NCL's activities. The laboratory estimated that in the medium term, technologies developed domestically could have market relevance in the following cases:

(a) Technically and commercially competitive technology with global markets. Since imports are to be financed by exports, there is a need to produce goods and services for foreign markets. R&D should be oriented towards domestic needs, as well as to international market demands. This could include the development of environmentally cleaner products and processes (such as zeolite detergents).

(b) Technologies using innovative processes and based on domestically available raw materials and resources for the Indian and the export markets. Examples include pesticides based on natural products, such as Neem, and enzymes from micro-organisms.

(c) Packaged technologies, in terms of basic engineering and operating guarantees, which can compete with similar foreign packages. Laboratories such as NCL would have to evaluate the possibility of providing direct project engineering inputs, or of collaborating with foreign engineering companies in packaging these technologies. Work on both options is now underway.

(d) Process and product development of specialities which are largely proprietary, with substantial domestic market and export potentials and where foreign technology is unlikely;

(e) Upgrading of existing processes for product diversification. Such efforts would include energy and process optimization, alternative routes for cost reduction, and new product grades. In the past, Indian industry depended on foreign licensors for such improvements, which now may be difficult on account of limited foreign exchange availability.

(f) Processes which eliminate hazardous chemistry and make use of locally available raw materials, for example, non-phosgene/non-MIC routes for pesticides, polymers and chemicals.

(g) Processes and products adding value to raw materials mainly available in India or in other developing countries, and which could represent opportunities for promoting a specific competitive R&D capacity. These could include molasses and alcohol-based chemicals, jute, castor oil and essential oils. Since raw material import for export production is allowed, R&D would emphasize value adding for foreign markets, irrespective of whether the raw material is locally available or whether the final product has a local market.

(h) Import-substitution products meeting the needs of existing production

technologies, such as catalysts, additives, auxiliaries and low-volume, high-value intermediates.

(i) Biotechnology products and processes for agriculture, of particular relevance to India's local problems.

(j) Processes for bioactive compounds, important for family planning, the fight against malaria and other tropical diseases and with export potential to other countries as well, for example, to Asia.

(k) Innovative rather than imitative processes in the case of bioactive compounds, that is, processes which can be protected by patents abroad, for example drugs and pesticides. New products of this type are unlikely to be introduced in the country by foreign companies if patents can not be obtained. International trade restrictions could, however, affect such exports of Indian drugs and pesticides.

(l) Commercially viable small plants, modular in design, capable of producing speciality chemicals, etc. for the Indian market. Foreign companies would not be expected to enter areas where plant capacities are low and where India would not offer strategic advantages in terms of entry to global markets.

(m) Closely guarded technologies unlikely to be transferred to India; for example, hydrogen peroxide; similarly, chemistry-intensive projects, where foreign technology is not easily available, for example plant growth regulators such as Brassinolide.

(n) Increased sale of industrial and intellectual services within India and abroad. NCL has made a beginning by offering consultancy services to China. Other contracts are under negotiation. Possibilities of selling inventions rather than complete process technology could also be explored. Another important opportunity may lie in the export of software services for process modelling, simulation and control.

(o) R&D collaboration with foreign companies, making optimal use of Indian R&D scientific and technical skills, that is, high-level professionals available at a cost lower than in other parts of the world. NCL already has agreements for contract research with some foreign companies.

86. The above-listed elements proceed from the internal analysis made at NCL and of course have a great deal to do with how NCL keeps its "antennae" out while cementing its relationship within the market. One example is how it makes and strengthens contacts and links with enterprises and producing firms. Some of the initiatives taken by NCL in this context are described in the following section.

C. Initiatives at the NCL level

87. Remaining competitive will depend on technology to a great extent. NCL realized that the multi-disciplinary background of its consultancy practice should be of assistance to its clients as they develop future business strategies. It decided to provide services in various new aspects. Information-based products and services to be introduced are: technology monitoring, assessment and forecasting; multi-client studies on emerging technologies and new products; services for corporate planning and diversification; simulation, process control and engineering software; and technical information retrieval, collection, documentation and management. NCL also decided to create incentives for encouraging application-oriented R & D and for the transfer and application of the results, as shown below.

1. Promoting interaction with financial institutions

88. NCL's experience indicates that for a new technology to attain commercial success, the interaction of entrepreneurs in industry, research laboratories and

financial institutions is crucial. Research institutions like NCL, in the risky but challenging area of technology generation, need innovative partners and new relationships, in other words, it must work with people ready to take a risk with unproven new technologies and in new markets.

89. It is not easy to build such relationships, especially when the capital for entrepreneurs has been a scarce commodity for such new ventures. Here, the guidelines on venture capital issued by the Government of India in 1988 for application by financial institutions are helpful. They are intended to facilitate access to capital for commercializing new untried technologies and backing potential first-generation entrepreneurs. Convinced that these venture capital schemes can act as catalysts in supporting domestic technology development in India, NCL has over the last three years systematically developed contacts with such financing institutions, participating in joint meetings with research institutions and industry to see how effectively such interactions could be built up.

90. Financing 'risk' is something new in India; indeed, the definition of 'risk' itself is somewhat blurred. However, there is currently a trend towards supporting processes not yet proven abroad. It is useful to illustrate this with NCL's experience in this area. The laboratory developed a process for the conversion of methanol to acetic acid, formerly in the hands of transnational corporations, for which it employed a nickel catalyst rather than the rhodium used in the conventional process. A medium-sized company, Gujarat Alcohol and Allied Chemicals Ltd. (GAAC), came forward to commercialize this technology. GAAC and NCL negotiated with the Industrial Development Bank of India (IDBI), which decided to provide venture capital for this project. In the new liberalization environment, which includes possibilities for technology imports, the company has decided to postpone the implementation of the acetic acid project, but will use the same technology for manufacturing propionic acid on a commercial scale. This is a "golden triangle" example of a company willing to take a risk on an unproven technology, a national laboratory producing an innovation of international scope (NCL was granted a US patent[11]), and a development bank willing to fund a project whose technical feasibility was not yet established.

91. NCL's rapport with financial institutions has become so strong that one of the authors of the present study, R.A. Mashelkar, is on the Board of Directors of the Technology Development & Information Company of India Ltd. (TDICI), one of the venture capital companies[12]. In addition, the firms involved in venture capital financing are increasingly requesting NCL to participate in the evaluation of development projects. Moreover, the laboratory has started marketing venture capital. In association with venture capital companies, it has been promoting the concept of "technology plus project finance". Under this scheme, NCL shares advance information on new innovative projects with venture capital companies. These companies evaluate the projects from the techno-economic angle and indicate their willingness to provide venture capital for commercialization. NCL then contacts potential customers, informing them that in addition to technical know-how, finance can be made available for commercializing these new, untried technologies. Such a scheme is expected to speed up the commercialization of domestic technologies, and to benefit the laboratory, and industry, as well as financial institutions.

2. Incentives for team efforts

92. In the present competitive setting, scientists within publicly-funded R &

---

[11] Patent no. 4.902.659.

[12] The closer relations with financial institutions have also led to the appointment of Dr. R. A. Mashelkar to the Technology Board of Industrial Credit and Investment Corporation of India Ltd. (ICICI) and the Governing Council of Programme for Advancement of Commercial Technology (PACT - a USAID funded programme in India).

D organizations are also required to act as "entrepreneurs", in the sense of looking forward, assessing and taking soundly-judged risks rather than following day-to-day procedures. The value and personal-management systems at research laboratories have to motivate staff and reward teamwork as well, for example in manufacturing major products, services and technologies. Today, progress in modern science and technology cannot be made without a strong interdisciplinary effort. The question arose of how to fund such a reward system outside the prevalent government procedures. It was felt that a foundation or an association under the Societies Registration Act and/or the Public Trust Act should be formed for this purpose. The NCL Research Foundation has been registered as a Public Trust. In order to create a funding pool for awards, the Director of NCL approached a number of client companies for financial support, and received a positive response. The Foundation has decided to give annual awards for the best technology commercialized, the highest external earnings from industry, the new initiatives taken by the R & D support system, and for special individual achievements.

93. These awards are in addition to normal CSIR incentives available to scientific employees, some of which are as follows: (i) All CSIR scientists are allowed to do industrial consultancy work; the individual scientist's share is limited to Rs. 100,000 per year; (ii) CSIR reimburses employees for the membership fees of professional societies; (iii) CSIR has a number of exchange programmes with countries such as the USA, U.K., France and Germany, which provide plenty of opportunities to travel abroad; (iv) a special CSIR scheme has been set up to identify and encourage young scientists of exceptional talent. This scheme includes cash prizes as well as special research funds.

3. Kite flying projects

94. Should "good science automatically lead to good technology", it would be of utmost importance that fundamental research of 'explosive creativity' be promoted in research laboratories like NCL. Although very high-level scientific work is undertaken in certain areas, ideas that are truly original are often not pursued. This is a result of several constraints: When such truly original ideas emerge, a fair evaluation is often difficult to obtain among one's peers, since the idea could be far ahead of its time; another constraint is giving problem areas for work to Ph.D students, which cannot be completed within a specific time frame. It was therefore felt that NCL was in a unique position to set a new trend by supporting truly 'kite flying' ideas for testing new concepts.

95. CSIR has allowed laboratories to retain their earnings from industry. NCL management decided that 25 per cent of the net earnings would be used to support truly innovative "kite flying ideas", and the remaining 75 per cent would be recycled back to those who earned the money in the previous year in the proportion in which they earned it. It is hoped that this will provide incentives for people to work harder and earn more from industry. The concept of 'kite flying projects' has caught on very well and has introduced a new culture at the NCL, for venturing into daring intellectual pursuits.

4. Export of R & D and know-how

96. As we move into the next century, the trend is towards globalization of business as well as of R & D. NCL has consequently decided to venture out into the global market. Today it is undertaking research contracts on behalf of international companies abroad, drawing upon the unique feature of Indian R & D, namely its international-calibre scientific and technical skills, which it can provide at a cost lower than in other parts of the world. Catalysts manufactured under know-how developed at NCL are being exported. The laboratory has recently transferred know-how for high-tech catalysts to a multinational company in Europe. Negotiations are in progress for export of other technologies and services in the field of catalysts, polymers and biotechnology.

5. Patents

97. If there is to be greater involvement in the global market of products, technologies and services, the "patent consciousness" of scientists will have to improve, and laboratories will need to protect their intellectual property worldwide. Accordingly, there is an increasing tendency towards filing more patents. The number of applications filed in India exceeded 50 in 1990. During 1990-91, five US patents were granted to NCL. These patents are in high-tech areas, such as those relating to acetic acid (formerly a monopoly of BP-Monsanto), reforming, natural gas conversion to middle distillates, non-MIC/non-phosgene route to carbamate pesticides, and safer and innovative processes for the manufacture of intermediates for ranitidine, the largest selling drug in the world today. Based on the US patent on acetic acid, negotiations are currently going on with two companies for exploitation of the patent in the USA.

6. Strategies for maximizing returns from industrial research

98. Based on recommendations of the CSIR Review Committee (1986), national laboratories have been compelled to become proactive with regard to their ability to engage in meaningful industrial research and technology transfer, while earning a portion of the operating cost from industrially sponsored research, royalties, premiums, consultancy and technical services. Such earnings have become imperative for a large laboratory like NCL, particularly since public budgetary support has remained at the same level, and owing to the low value of the Indian rupee. Such an income can sustain the level of R & D that is necessary to meet future challenges and make an effective use of skill and resources. It was therefore thought essential to have a continual annual improvement in the external cash flow, which in several years would mean a return on the investment that will generate cash flow for growth.

99. The following initiatives have been undertaken along these lines at NCL: a frank analysis of the performance in the past few years, in order to see what lessons could be learned in improving industrial performance and in terms of external cash flow; and the identification of many deficiencies in the system, subsequent to which proper corrective actions have been taken. The latter include the following measures: (i) improved project selection and evaluation mechanisms; (ii) better choice of collaborators; (iii) proper internal and external reporting systems for industrial projects; (iv) improved terms of sponsorship/know-how transfer with due consideration of the opportunity cost; (v) getting closer to the realities of the market place and obtaining a very clear definition of market targets; strict scrutiny of grant-in-aid projects and of external aid, with emphasis on 'quality of spending', rather than 'quantity earned'; (vi) identification of portfolios of short, medium and long-term industrial R & D projects, based on analysis of the market for products, technology; a study of inputs required from NCL, including a timeframe for development, and of returns in terms of license fee and royalties; (vii) linking budget to projects/programmes and the recycling of CSIR return-to-project earnings; (viii) promoting value addition in NCL's sale of technology by combining basic engineering packages by an outstanding team of process engineers; (ix) a drive to increase industrial consultancy earnings with a strategy to sell knowledge-based information in a properly packaged form; and (x) creation of a project monitoring and evaluation cell.

100. Many of these measures required planning from a technical and business perspective, along with the strengthening of NCL's marketing and R & D management base. Until recently, several of these activities were undertaken by NCL staff in a decentralized manner, but the need was felt to further improve coherence between various activities. Accordingly, a Project Planning and Development (PPD) Unit was created with the following duties and objectives: to provide (i) scientists with information on technological and market requirements; (ii) to bring together companies and appropriate NCL division/scientists; (iii) to arrange for appropriate contract work to be undertaken by NCL; (iv) to act as a principal commercial agent for marketing NCL research and technology; and (v) to maximize returns from contract research and consultancy. This Unit is staffed

by young and dynamic experts, with considerable experience in research, technology, marketing, industry and government. These experts follow the market by interacting with industry, scanning patent literature, keeping track of international business, trade and technology development, etc. In view of the wider perspective at NCL, and because its aim is to function as a corporate entity, the laboratory has competent personnel in other disciplines, e.g. contract and patent, law, finance, or budgeting and costing. The PPD Unit does a pre-research appraisal of new projects, products and processes from a technical and commercial angle. All new research proposals and contracts are screened and evaluated by the PPD unit before they are sent out to client companies, to ensure that returns to NCL are maximized.

101. The laboratory has made special efforts during recent years to get closer to entrepreneurs in industry, understand their needs, and accordingly modify its offer of processes and services. It participates regularly and conducts meetings with industry associations, where senior scientists make formal presentations on what NCL can offer". This kind of interaction leads to a better appreciation by industry of the laboratory's capabilities, as well as to business development. NCL is a formal member of the Indian Chemical Manufacturers Association (ICMA) - which is probably the first time that a national laboratory has joined of an industry association. The information obtained from various committees of ICMA is used as input for NCL business planning.

102. NCL also regularly brings out brochures highlighting its R & D efforts in different areas, which it distributes to in-house R & D units of industry. NCL is targeting its information and contacts among a small number of industrial customers. Based on its database for industrial companies, operating technologies and their future growth plans, a short list of potential customers has been drawn up. Information on new projects/innovations in particular product groups is now being exchanged with these companies with a view to generating business for contract research or licensing. The effectiveness of this approach is demonstrated by the very high percentage of proposals converted into development projects funded by the industry.

103. The laboratory primarily enters into three kinds of development arrangements with industry. The first concerns direct licensing, which means release of know-how at the laboratory or pilot-plant level. Licensing on a non-exclusive basis is normally done for projects identified and funded by the laboratory. The second type of arrangement relates to sponsorship, meaning projects identified by the laboratory or industry, but funded by industry. Since industry takes risks by funding a project at the concept stage, a limited exclusivity of three to five years is given to the sponsored party. When the exclusivity period expires, the laboratory is free to release the know-how to other parties. The third concerns the collaborative mode: This involves combining the strengths of laboratory and industry, necessary for the particular project to succeed. In such cases, in addition to limited exclusivity of three to five years, intellectual property is treated as joint property of the laboratory and the sponsor, and benefits derived from third-party licensing are shared as per mutually agreed terms. All the above arrangements are formalized through a legal agreement, which is specifically drawn up for each client on a case-to-case basis. The laboratory's as well as industry's confidence in NCL's ability to develop and transfer technologies have grown to an extent where sponsored projects which have the possibility of a "multi-client sale" are being offered on a non-exclusive basis. Some contracts now have a provision for cross-licensing.

104. NCL's experience with the PPD approach has proven highly satisfactory, compared to external commercialization agencies such as the NRDC. Technology marketing is a specialized job, and is best done by a set of people having

---

" In order to bridge the communication gap between NCL and the industry, the laboratory director recently wrote letters to chief executives of about 300 industrial units, giving information on industry-oriented R & D projects at NCL and also on the services that NCL can offer to them.

expertise in the field and closely involved with development work. By closely interacting with industry and the research team right from the pre-research phase to final development, the PPD Unit is able to establish the right contacts and gain the right perspective with both groups, an important factor for success.

105. The net result of the above policies and strategies is that the laboratory's industrial earnings have increased by 250 per cent over the last three to four years. The share of private sector to public sector in these earnings has changed from 50:50 to 90:10. Consultancy earnings have gone up by 300 per cent during the same period, while foreign exchange earnings have increased many times.

7. Value adding and upgrading

106. The laboratory's confidence in its interactions with industry and in its ability to earn a profit from such a source have resulted in a number of bold initiatives: The laboratory has obtained a considerable loan, (Rs. 100 million) from a financial institution under the World Bank project. This is not a grant-in-aid; the loan must be repaid from NCL earnings. The money will be used essentially for upgrading pilot plant facilities. For the past two decades, NCL has been developing process technologies. In most cases, work has been restricted to process development on a laboratory scale and to transferring the results to industrial enterprises. Commercial success of the results has mainly depended upon the ingenuity of the entrepreneur in translating the laboratory-scale process into a workable commercial one. No scale-up or design-data generation has been done at NCL, due to the lack of pilot plant facilities.

107. In recent years, the production of most organic products has involved a complex multi-step synthesis, with an important recovery of unreacted raw materials and solvents, as well as separation of finished products. NCL's customers have been insisting on the transfer of know-how on at least a pilot-plant scale of reasonable size, generation of basic design data and performance guarantees. Although in some cases NCL has made an attempt to scale-up the process with financial inputs from industry, this has not been possible for every process; industry has not been in a position to fund the pilot plant activities. NCL has therefore been unable to compete with imported technologies, since foreign suppliers of know-how have offered technologies from running commercial plants, and accordingly performance guarantees as well. This problem became very acute in the late 1980s a result of government liberalization policies and reduced the demand for NCL processes on a laboratory scale.

108. Even in cases where know-how was transferred on a laboratory scale, NCL has been unable to get a fair price for its technologies due to inadequate pilot plant facilities and engineering inputs. The consequent loss of revenue to NCL has been considerable. Additionally, due to the inadequate pilot plant facilities, NCL has relied on transferring the technology to an industry, thereafter engaging in joint transfer of technology to subsequent clients. This model, although sound, does not ensure multi-client sale with benefits to NCL. World Bank support for pilot plants is expected to help, addressing particularly pilot plants for catalysis, polymers and organic chemical technology. In addition, NCL is aiming at improving its process engineering capabilities. This will strongly reinforce the laboratory's capacities and strengthen its technological base.

D. Concluding remarks

109. At the broader policy level, there is a feeling among economic actors involved in R & D that more remains to be done by both government and the industrial sector. Pertinent aspects include the following:

(a) Beyond recognizing the relevance of technology innovation for the future, the main actors involved (i.e., government, industry, educational and R & D institutions) must focus on their common goals and strengthen their ties.

(b) On the demand side of skills, the syllabi of educational institutions of science and technology must concentrate on truly relevant areas with

respect to new challenges. Leading organizations such as the Indian Institute of Science, Bangalore; the Indian institutes of technology and the Bombay University Department of Chemical Technology, among others, appear to have the necessary capabilities.

(c) Intellectual property rights legislation needs to be reviewed in the light of new policy goals.

(d) As representatives of industry R & D have noted, these organizations could benefit from the approach applied to publicly-funded R & D institutes as far as the import of equipment and instruments is concerned. Other incentives could also be considered for promoting industry R & D and the faster commercialization of results.

(e) While publicly-funded R & D organizations will have to increasingly become accountable for results, in order to achieve key outputs these organizations require adequate funds in specific areas of their expertise. This is a matter of current concern, particularly to publicly-funded laboratories, whose budget allocations from government have been severely trimmed and who have been directed to seek funds from industry.

(f) Management of technology and of industrial research will have to be emphasized, and

(g) Industry needs to ensure its access to the brightest talents, who graduate from premier Indian institutes but often tend to migrate to the West; accordingly, it also should initiate its own programmes along these lines.

110. To meet present challenges, the CSIR appointed a committee to suggest ways and means of creating an enabling environment for the commercialization of the CSIR knowledge-base. The summary of the report submitted by the above committee to the CSIR indicated, inter alia, that the eighth Plan allocations represented around 40 per cent of CSIR's real requirements, and that, together with the freeze of the non-Plan expenditures at the 1990-91 level, this meant a decline in government grants in real terms of over 20 per cent annually. The major clientele of CSIR for contract R & D had hitherto been the government departments, but these were now facing similar budgetary constraints. The report stressed the need to reorient R & D programmes and activities to make them more user responsive, improve CSIR's R & D productivity, optimize the returns on investments already made, and effectively manage and market the CSIR knowledge-base. It stressed the wide-ranging multidisciplinary expertise and capabilities of CSIR, which could be usefully applied by Indian industry to achieve global competitiveness. It also pointed out that globalization offers opportunities beyond India. The report's recommendations covered aspects concerning marketing, staffing, training, financial support to marketing, marketing mechanisms, provision of incentives and flexibility in procedures[34]. It appears that remarkable changes in attitudes have started to take place in publicly-funded R & D institutions: new strategies for stronger industry interactions and market orientation are reported to be emerging, on the basis of a rational and radical reorientation[35].

111. The present report has considered specific case-related aspects concerning the utilization and commercialization of publicly-funded R & D results in India vis-à-vis the NCL experience. The following summarizes some recommendations proposed by the authors and based on their experiences in the context of an

---

[34] The committee was chaired by one of the authors of the present report, Dr.R.A. Mashelkar.

[35] See Mashelkar, R.A. "Developing World and High Technology: The Indian Perspective", unpublished paper of a lecture delivered at the conference on "High Technology and Profitability for the 21st Century", organized by the International Herald Tribune and the International Chamber of Commerce, Hong Kong, 17-18 May 1993.

institution recognized as a solid R & D centre, operating in a large developing country, with a significant S & T infrastructure.

112. Confidence-building by a laboratory, along with an increase in expertise and capabilities, facilitates the utilization and commercialization of R & D, thus progressively boosting competitiveness. Moreover, the effective use and commercialization of R & D will depend on industry. Firms require leaders as managers, who are willing to risk new markets and try out new technologies while having a clear understanding of the role of R & D. In developing countries such as India, which is gradually opening up to the market economy and constructing a setting in which competitive R & D can thrive, publicly-funded R & D institutions may have to continue playing a major role in R & D as well as promoting the commercialization of its results. Initiatives for promoting research in industry itself, and towards establishing workable linkages between publicly-funded R & D systems, educational institutions and the enterprise sector will in the long run become increasingly important. To meet the challenges posed to the R & D setting in developing countries, the authors propose the following elements:

(a) Concentrate first on technology absorption and adaptation. This means, inter alia, efforts ranging from stimulating the absorption and upgrading of imported technology to strengthening the technological base, as well as negotiating further technology acquisition. Efforts to promote domestic technology development would have to follow.

(b) Encourage joint research programmes between industry and publicly-funded R & D institutions, taking full advantage of firms' production facilities and experience, as well as of the expertise in publicly-funded R & D institutions.

(c) Facilitate financial assistance for setting up common R & D facilities and pilot plants. Such pilot plants are vital for industrial R & D, and venture capital on soft terms is one way to support such technology development and pilot production facilities.

(d) Makes it understood that for a technology to remain competitive, there is a need for sustained R & D efforts over a period of time. Thus industry can adapt to technological, environmental, economic and regulatory changes.

(e) Focus R & D on selected areas for developing competitiveness at the world level, carefully chosen on the basis of factors such as raw-material advantages and the profile of available skills. R & D institutions accordingly will have to join hands with a number of industrial partners and agencies who can facilitate technology development and transfer.

(f) Promote and strengthen design engineering and engineering consultancy services in the developing countries, which are essential for translating know-how into commercial production. Engineering consultancy provides an essential link between R & D institutions and industry, and thus promotes effective transfer of technology.

(g) Consider the development of a capability for total systems engineering; process development and project management should be developed with foreign collaboration, if required.

(h) Concurrently, promote and support the domestic development of capital goods. The objective would be to offer a total technology package, including know-how, engineering and performance guarantees.

(i) Improve technology utilization efforts, including through strengthening technology management capabilities at both the policy-making and operations/technical decision-making levels, creating an awareness of the importance of incorporating technological considerations into development and planning; and fostering the integration of such considerations into national planning.

(j) Strengthen technology information systems and implement a technology information service, including information on domestic and imported technologies, and analytical inputs for various stages of technological acquisition. Lack of this type of information has been considered as the weakest spot of publicly-funded R & D system in developing countries.

(k) In R & D organizations, strengthen project planning and technology transfer structures for continuously screening new ideas, selecting projects and evaluating their commercial viability.

(l) Develop technology marketing organizations and different mechanisms for technology transfer and utilization, including for aspects concerning the protection of intellectual property rights.

113. Of all elements, the most essential is the upgrading of the human-resource base, through training and exposure to R & D activities in enterprises, in different institutions of the developed countries or through overseas training for young scientists, engineers and consultants. In this context, a critical step is to ensure the mobility of scientists from national laboratories to enterprises and vice-versa. International R & D collaboration with the support of multilateral aid agencies, as well as relations with the latter for promoting of cooperation among developing countries in this domain, can contribute to building up the technological capabilities necessary for increased, effective R & D competitiveness.

كيفية الحصول على منشورات الامم المتحدة

يمكن الحصول على منشورات الامم المتحدة من المكتبات ودور التوزيع في جميع انحاء العالم . استعلم عنها من المكتبة التي تتعامل معها أو اكتب الى : الامم المتحدة ،قسم البيع في نيويورك او في جنيف .

如何购取联合国出版物

联合国出版物在全世界各地的书店和经售处均有发售。请向书店询问或写信到纽约或日内瓦的联合国销售组。

HOW TO OBTAIN UNITED NATIONS PUBLICATIONS

United Nations publications may be obtained from bookstores and distributors throughout the world. Consult your bookstore or write to: United Nations, Sales Section, New York or Geneva.

COMMENT SE PROCURER LES PUBLICATIONS DES NATIONS UNIES

Les publications des Nations Unies sont en vente dans les librairies et les agences dépositaires du monde entier. Informez-vous auprès de votre libraire ou adressez-vous à : Nations Unies, Section des ventes, New York ou Genève.

КАК ПОЛУЧИТЬ ИЗДАНИЯ ОРГАНИЗАЦИИ ОБЪЕДИНЕННЫХ НАЦИЙ

Издания Организации Объединенных Наций можно купить в книжных магазинах и агентствах во всех районах мира. Наводите справки об изданиях в вашем книжном магазине или пишите по адресу: Организация Объединенных Наций, Секция по продаже изданий, Нью-Йорк или Женева.

COMO CONSEGUIR PUBLICACIONES DE LAS NACIONES UNIDAS

Las publicaciones de las Naciones Unidas están en venta en librerías y casas distribuidoras en todas partes del mundo. Consulte a su librero o diríjase a: Naciones Unidas, Sección de Ventas, Nueva York o Ginebra.

Printed at United Nations, Geneva
GE.93-53728–October 1993–2,760

United Nations publication